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A Davis's Notes Book



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A-type Natriuretic Peptide (ANP)

22–77 pg/mL; SI units: 22–77 ng/L

- ▶ Lavender-top tube. Immediately send to lab on ice. Specimen may need to be fasting; check with lab.
 - Secreted by atrial myocardium; exerts an antihypertensive effect by increasing the renal excretion of sodium and water.
 - Secreted from the atria in response to atrial wall stretch.
 - Less useful than B-type natriuretic.

Acid-fast Bacillus Stain (AFB)

Negative for acid-fast organisms

- ▶ Sputum specimen sent in a sterile collection cup. Gastric washings/aspirates, urine, cerebral spinal fluid (CSF), other body fluids, or tissue samples may also be tested.
 - Sputum samples should be induced in the early morning to obtain the best specimen.
 - Collect specimens for 3 days.
 - Tests for *Mycobacterium tuberculosis*, atypical mycobacteria, or other acid-fast bacteria. See Tuberculosis Culture.

Acid Phosphatase (ACP, Prostatic Acid Phosphatase, PAP)

<2.6 ng/mL or <0.5 IU/L; SI units: 2.2 – 10.5 U/L

- ▶ Red-top tube.
 - Assess prostate cancer metastasis, treatment effectiveness.
 - Infrequently done; usual test is PSA, prostate-specific antigen.

ACTH (Adrenocorticotropic Hormone)

AM: <80 pg/mL; SI units: <18 pmol/L

PM: <50 pg/mL; SI units: <11 pmol/L

- ▶ Green-top tube.
 - Assess signs and symptoms of adrenocortical dysfunction.
 - Sample must be iced and sent to lab immediately.

ACTH Stimulation Test (Cosyntropin Stimulation Test)

>7 µg/dL over baseline in rapid screening test

>40 µg/dL over baseline in 1- or 3-day test

- ▶ Green-top tube.
 - Differentiate between pituitary-induced adrenal dysfunction and adrenal insufficiency.
 - Test involves obtaining a baseline ACTH level, administering cosyntropin (a synthetic ACTH-like drug) over a prescribed period, and drawing repeat ACTH levels.

Activated Partial Thromboplastin Time (aPTT)

See Partial Thromboplastin time (PTT).

Antithrombin III (AT-III)

21–30 mg/dL; SI units: 210–300 mg/L

- ▶ Blue- or red-top tube.
 - Assess patients with thromboses.
 - Patients with low levels are resistant to heparin therapy.

Alanine aminotransferase (ALT)

10–35 U/L; SI units: 0–0.58 mkat/L

- ▶ Red-top tube.
 - Enzyme found in liver cells.
 - Used in diagnosis of liver, biliary, and pancreatic disease.

Albumin

Adult: 3.5–5 g/dL; SI units: 35–50 g/L

Child: 3.8–5.4 g/dL; SI units: 38–54 g/L

- ▶ Red-top tube.
 - Main plasma protein; helps maintain osmotic pressure. Decreased albumin causes fluid shifts and resultant edema.
 - Levels decrease in renal or hepatic disease, acute infection, malnutrition, malignancy, diabetes, and many other chronic and acute conditions.

Albumin Cobalt Binding Test (ACB Test) (Ischemia-modified Albumin [IMA])

< 85 U/mL

- ▶ Red-top tube.
 - A new cardiac marker test. The binding properties of albumin change when it comes into contact with ischemic heart tissue (ischemia-modified albumin [IMA]) making it less able to bind with cobalt. When a cobalt solution is added to the serum, cobalt binds to the normal albumin but not to IMA. More free, or unbound, cobalt indicates the presence of abnormal albumin.
 - Level rises within a few minutes of the onset of cardiac ischemia. Allows a greater window of time for therapeutic intervention as other markers only detect cardiac muscle necrosis, not ischemia.
 - Used in conjunction with ECG and troponin levels to evaluate etiology of chest pain.

Albumin/Globulin Ratio (A/G Ratio)

- >1
- ▶ Calculated from total protein and albumin levels.
 - Total protein – albumin = globulins. Albumin ÷ globulins = A/G ratio.
 - Serum protein electrophoresis has replaced the A/G ratio.

Aldosterone, Serum

7–30 ng/dL; SI units: 190–832 pmol/L (drawn in upright position)
 3–16 ng/dL; SI units: 80–440 pmol/L (drawn in supine position)

- ▶ Red-or green-top tube.
 - Aldosterone is a potent mineralocorticoid that regulates sodium, potassium, and water balance.
 - Used with plasma rennin levels to distinguish between primary or secondary (more common) hyperaldosteronism.

Aldosterone, Urine

2–26 µg/24 hr; SI units: 6–72 nmol/24 hr

- ▶ 24-hr urine collection.
 - Aldosterone is a potent mineralocorticoid that regulates sodium, potassium, and water balance.
 - Used to diagnose primary or secondary hyperaldosteronism.

Alkaline Phosphatase (ALP)

Adult: 42–136 U/L
 Child: 50–230 U/L

- ▶ Red-top tube.
 - Enzyme found predominately in the liver, biliary tract, and bone.
 - Useful in assessing liver and bone disease.
 - ALP isoenzymes distinguish between liver and bone disease. ALP₁ is hepatic; ALP₂ is from bone.

Alpha-Fetoprotein (AFP, a-Fetoprotein)

Men, Nonpregnant Females: <16 ng/mL; SI Units: <16 mL
 Pregnant Females at 15–18 Weeks' Gestation: 10–150 ng/mL; SI units: 10–150 mL

- ▶ Red-top tube.
 - In men and nonpregnant females as a tumor marker to aid in diagnosis of hepatocellular carcinoma, testicular tumor, ovarian cancer. May be elevated in alcoholic cirrhosis.
 - In pregnancy to detect fetal neural tube defect, multiple pregnancy, fetal distress, fetal death.

AmmoniaAdult: 15–45 $\mu\text{g/dL}$; SI units: 11–35 $\mu\text{mol/L}$ Child: 29–70 $\mu\text{g/dL}$; SI units: 29–70 $\mu\text{mol/L}$

▶ Green-top tube.

- Ammonia forms when protein is broken down by bacteria in the intestinal tract. It is then converted to urea by the liver and excreted by the kidneys.
- Elevated in liver failure. Elevations manifest as encephalopathy (lethargy, confusion, tremors, coma).

Amylase, Serum

Adult: 60–160 Somogyi U/dL; SI units: 30–70 U/L

▶ Red-top tube.

- Secreted by the pancreas and elevated in pancreatic disorders.
- Damaged or obstructed pancreatic cells cause amylase to spill into lymph ducts and the peritoneum where excess amylase is picked up by the blood.

Anion Gap (AG)

8–16 mEq/L

▶ Calculated from electrolyte values.

- Anion gap equals the difference between the cations (sodium and potassium) and the anions (chloride and bicarbonate).
- $(\text{Na}^+ + \text{K}^+) - (\text{Cl}^- + \text{HCO}_3^-) = \text{AG}$
- Elevated AG (>17 mEq/L) is associated with metabolic acidosis.
- Decreased AG (<8 mEq/L) is associated with metabolic alkalosis (see ABG section in this Tab).

Antibodies, Auto

- ◆ Anticentromere antibody
- ◆ Anti-DNA antibody
- ◆ Antiglomerular basement membrane antibody
- ◆ Antimicrosomal antibody
- ◆ Antimitochondrial antibody
- ◆ Antimyocardial antibody
- ◆ Antineutrophil cytoplasmic antibody (ANCA)
- ◆ Antinuclear antibody (ANA)
- ◆ Antiparietal cell antibody
- ◆ Antiscleroderma antibody (SCL 70)
- ◆ Antismooth muscle antibody
- ◆ Sjögren syndrome antibody (SS-A)

Negative. Reference ranges and measurement units for individual tests vary as does the amount of detectable antibody that constitutes a positive result. Results may be reported as the amount of antibody detected and if the values are considered negative, positive, or equivocal.

► Red-top tube.

- Autoantibodies are proteins created by the immune system that attack the body's own tissues or organs.
- Autoantibodies represent a failure by the immune system to distinguish between foreign proteins and the body's own tissues.
- Elevated autoantibody levels are found in people with autoimmune disorders such as systemic lupus erythematosus (SLE).
- Autoimmune disorders may be organ specific as in Graves' disease, or systemic, as in vasculitis.

Antidiuretic Hormone (ADH); ADH Suppression Test

ADH: 1–5 pg/mL; SI units: <1.5 ng/L

ADH suppression test: 80% of waterload excreted in 5 hr; Urine osmolality ≥ 100 mmol/kg; Urine to serum osmolality ratio > 100 ; Urine specific gravity < 1.003 .

► Red-top tube, *plastic*.

- ADH controls the amount of water resorbed by the kidney.
- Inadequate ADH secretion results in diabetes insipidus (DI).
- Excess secretion of ADH related to various cancers (lung, pancreas, urinary tract, blood) results in syndrome of inappropriate ADH (SIADH).

Antistreptolysin O/Antistreptococcal O Titer (ASO)

Adult and preschool age child: <100 IU/mL

Child (school age) : <200 IU/mL

► Red-top tube

- Streptolysin is an enzyme secreted by beta-hemolytic streptococci. It causes an antibody response that begins to rise 1 week after streptococcal infection and peaks in 2–3 weeks.
- High serum ASO levels are seen with acute rheumatic fever, poststreptococcal glomerulonephritis, and collagen diseases.

<i>Apolipoproteins</i>		
	Coventional	SI Units
Apo A-I		
◆ Male	81–166 mg/dL	0.81–1.66 g/L
◆ Female	80–214 mg/dL	0.8–2.14 g/L
Apo B		
◆ Male	46–174 mg/dL	0.46–1.74 g/L
◆ Female	46–146 mg/dL	0.46–1.46 g/L
Lipoprotein (a)		
◆ Caucasians		
● Male	2.2–49.4 mg/dL	0.02–0.49 g/L
● Female	2.1–57.3 mg/dL	0.02–0.57 g/L
◆ African-Americans		
● Male	4.6–71.8 mg/dL	0.05–0.72 g/L
● Female	4.4–75 mg/dL	0.04–0.75 g/L

▶ Red-top tube.

- Proteins that transport cholesterol in the bloodstream.
- Used to evaluate the risk of coronary artery disease.
- Ratio of Apo-I to Apo B is calculated to further stratify risk.

Arterial Blood Gases (ABGs)

Normal ABG Results (US System of Measurements)

pH	PaO ₂	PaCO ₂	O ₂ Saturation	HCO ₃	Base Excess
7.35–7.45	80–100 mm Hg	35–45 mm Hg	95–100%	21–28 mEq/L	-2 to +2 mEq/L

Normal ABG Results (SI Units)

pH	PaO ₂	PaCO ₂	O ₂ Saturation	HCO ₃	Base Excess
7.35–7.45	10.6–12.6 kPa	4.66–5.98 kPa	95–100%	21–28 mmol/L	-2 to +2 mmol/L

Critical Levels: pH: <7.25 or >7.55; PaCO₂: <20 or >60; PaO₂: <45; HCO₃: <15 or >40; Base Excess: ± 3 mEq/L

- ▶ Collect in an air-free heparinized syringe. Send in ice slurry to lab immediately.
 - ABGs provide information about acid-base balance and the levels of O₂ and CO₂ in the blood.
 - ABG results may indicate decreased O₂ levels (hypoxia), decreased or increased CO₂ levels (hypo- or hypercapnia), acidosis (decreased pH), alkalosis (increased pH), and the degree of compensation.
 - ABGs are drawn to establish the diagnosis and severity of respiratory failure and manage patients with respiratory dysfunction, cardiac failure, renal or hepatic failure, trauma, multisystem failure, diabetic ketoacidosis, sepsis, and other serious conditions.

pH

- An indicator of hydrogen ion concentration. Controlled primarily by the ratio of bicarbonate ions (HCO₃⁻) to carbonic acid (H₂CO₃). The body can tolerate only small changes in blood pH. Levels outside this range lead to coma and death because vital proteins lose structural integrity and function.
- **Acidosis** and **alkalosis** refer to processes that alter the pH of blood.
- **Metabolic acidosis, metabolic alkalosis, respiratory acidosis, and respiratory alkalosis** are the four ways in which pH is altered. A patient often has two processes occurring simultaneously; for example, a

metabolic acidosis and a respiratory alkalosis. One process dominates and the other partially compensates.

- In metabolic processes, the bicarbonate concentration in the blood changes. Bicarbonate is a base controlled by the kidneys. Decreases in bicarbonate result in **metabolic acidosis** and increases result in **metabolic alkalosis**.
- In respiratory processes, blood pH is affected by carbon dioxide (CO_2) levels. Though CO_2 is technically a gas, it is regarded as a respiratory acid—the only acid that can be exhaled. It is the waste product of cellular metabolism and is carried by the blood to the lungs for excretion. If the lungs are unable to excrete it, CO_2 levels rise. Increased CO_2 levels in the blood result in **respiratory acidosis**. Decreased levels of carbon dioxide result in **respiratory alkalosis**.

PaO₂

- An indirect measure of oxygen content. Measures the tension (or partial pressure) of oxygen in the blood.

PaCO₂

- Measures the partial pressure of carbon dioxide in the blood. CO_2 content is controlled by the lungs, and PCO_2 is therefore a measure of how adequately the lungs are ventilating.

O₂ Saturation

- Indicates the oxygen content of the blood expressed as a percentage.

HCO₃

- Indicates the bicarbonate ion concentration in the blood, which is regulated by the kidneys. It is directly related to blood pH.

Base Excess/Deficit

- A calculated result that indicates the number of buffering anions in the blood and reflects the metabolic component of the patient's acid-base balance.

Aspartate Aminotransferase (AST)

Adult, child: 0–35 U/L; SI units: 0–0.58 μ kat/L

Newborn: 15–60 U/L

▶ Red-top tube.

- Enzyme found in cardiac muscle, liver, and skeletal muscle.
- Used primarily to evaluate patients with symptoms of liver disease (jaundice, liver enlargement, fatigue, weight loss, ascites, etc.).

B-type Natriuretic Peptide

0–100 pg/mL SI units: 0–100 ng/L

▶ Lavender-top plastic tube. Put on ice immediately. Specimen may need to be fasting; check with lab.

- Secreted by ventricular myocardium; acts as a vasodilator and increases renal excretion of sodium and water.
- Suppresses sympathetic tone and the renin-angiotensin system.
- Aids in the diagnosis of CHF.

Bence Jones Protein (Immunofixation [IFE], Protein Electrophoresis)

Negative

▶ Random or 24-hr urine collection. Refrigerate during collection.

- Identifies types of proteins abnormally present in urine.
- Used in the diagnosis of monoclonal gammopathies, lymphoproliferative diseases, multiple myeloma, macroglobulinemia of Waldenström, and amyloidosis.

Bilirubin, Total, Direct, Indirect

Adult, child: Total: 0.3–1 mg/dL; SI units: 1.7–20.5 μ mol/L

Direct: 0.1–0.3 mg/dL; SI units: 1.7–5.1 μ mol/L

Indirect: 0.1–0.8 mg/dL; SI units: 1.7–12 μ mol/L

Newborn: 1–12 mg/dL; SI units: 17.1–205 μ mol/L

Critical Level: Newborn: >15 mg/dL; SI units: >257 μ mol/L

▶ Red-top tube.

- Bilirubin is a by-product of the breakdown of hemoglobin.
- Most bilirubin is chemically attached (conjugated) to another substance. This is called *direct bilirubin*. Unconjugated bilirubin is called *indirect bilirubin*. Conjugated bilirubin is excreted in bile.

- High bilirubin levels cause jaundice and are seen in liver disease and biliary obstruction.
- In newborns, elevated bilirubin occurs with Rh or ABO incompatibility. Brain jaundice (kernicterus) develops at higher levels and can result in mental retardation, cerebral palsy, or blindness.

Bilirubin, Urine

Negative

- ▶ Random urine. Protect from light.
 - Used to detect bilirubin in the urine, which is not normal and indicates liver or biliary disease.

Bleeding Time

1–9 min (Ivy)

- ▶ Assessed by making a 1mm deep incision and noting time it takes for bleeding to stop.
 - Prolonged bleeding time may indicate defective platelet function, thrombocytopenia, von Willebrand's disease.
 - Affected by drugs including dextran, indomethacin, and NSAIDs.

Blood Cultures

Negative

- ▶ Blood culture bottles—one aerobic and one anaerobic.
 - Isolate and identify potentially pathogenic organisms causing bacteremia; establish the diagnosis of endocarditis.
 - Obtained when sepsis, meningitis, osteomyelitis, arthritis, bacterial pneumonia, fever of unknown origin, or occult abscess is suspected.
 - Strict aseptic technique and skin preparation are essential to collection.
 - Several sets of blood cultures are taken.

Blood Urea Nitrogen (BUN)

Adult: 10–20 mg/dL; SI units: 3.6–7.1 mmol/L

Child: 4–16 mg/dL; SI units: 1.4–5.7 mmol/L

Critical Levels:

- >40 mg/dL (not dehydrated/no history of renal disease)
- >100 mg/dL (patient with history of renal disease)
- >20 mg/dL increase in 24 hr (indicates acute renal failure)

- ▶ Red-top tube.

- BUN, a by-product of protein metabolism, is excreted primarily by the kidneys and therefore reflects kidney function.
- Elevated BUN (azotemia) occurs in most renal diseases; also rises with GI bleeding, dehydration, high protein diet, and CHF.

CD4/CD8 Ratio

See Lymphocyte Immunophenotyping.

***C. difficile* toxin (Pseudomembranous Colitis Toxic Assay)**

Negative

- ▶ Small amount of stool in a sterile container.
 - Assist in the diagnosis of antibiotic-related diarrhea.
 - The *C.difficile* bacterium releases a toxin that causes the epithelial lining of the colon to become necrotic.

C-reactive Protein (CRP); High-sensitivity CRP (hs CRP)

<10 mg/L; SI units: <10 mg/L

- ▶ Red-top tube. Some labs require a fasting sample.
 - Abnormal protein manufactured in the liver in response to inflammation and infection. Useful in evaluating autoimmune and infectious diseases and in monitoring treatment effectiveness.
 - CRP levels usually rise to 100 mg/L or more in the presence of inflammation and infection. For this purpose, the plain CRP test is used because it measures CRP in the 10–1000 mg/L range.
 - The high-sensitivity CRP test is used to assess risk of atherosclerosis in otherwise healthy adults. It measures CRP in the 0.5–10 mg/L range. Higher levels within this range are associated with an increased risk of atherosclerosis.

CA 15–3

<30 U/mL SI units: <30 kU/L

- ▶ Red-top tube.
 - Tumor marker monitored to assess response to treatment of invasive breast cancer.
 - Assess for recurrence of the disease.
 - Relative fall of CA 15–3 value reflects treatment effectiveness.

CA 19-9

<37 U/mL; SI units: <37 kU/L

- ▶ Red-top tube.
 - Tumor marker monitored to assess gastrointestinal, pancreatic, liver, and colorectal malignancies.
 - Monitor response to cancer treatment and assess for recurrence.

CA 125

0–35 U/mL; SI units: <35 kU/L

- ▶ Red-top tube.
 - Elevated in 80% of women with ovarian cancer.
 - Tumor marker monitored to assess effectiveness of treatment and assess for recurrence.

Calcitonin

Adult: *Males:* <40 pg/mL; SI units: <40 ng/L. *Females:* <25 pg/mL; SI units: <25 ng/L

- ▶ Green-top tube or chilled red-top tube. Specimen must be fasting.
 - Hormone produced by the thyroid gland.
 - Calcitonin reduces circulating calcium levels by increasing calcium's deposition in bone.
 - Used in the assessment of thyroid medullary cancer, lung cancer, pernicious anemia.

Calcium, Ionized

Adult: 4.4 to 5.3 mg/dL; SI units: 1.05–1.3 mmol/L

Child: 4.4 to 6.0 mg/dL; SI units: 1.2–1.38 mmol/L

Critical levels: > 6.29 mg/dL; SI units: >1.57 mmol/L or <3.1 mg/dL; SI units: < 0.78 mmol/L

- ▶ Red-top tube.
 - Ionized calcium is the metabolically active form of calcium.
 - Level is affected by the albumin level, blood pH, phosphate, magnesium, and bicarbonate levels.
 - Decreased by factors that bind calcium (citrate from transfused blood or free fatty acids from total parenteral nutrition [TPN]).
 - Decreased levels affect heart rhythm and neurologic status.

Calcium, Total

Adult: 8.2 to 10.5 mg/dL; SI units: 2.05–2.54 mmol/L

Child: 8.6–11.2 mg/dL; SI units: 2.15–2.79 mmol/L

**Critical levels: >12 mg/dL; SI units: >2.99 mmol/L (coma, death).
<7mg/dL; SI units: <1.75 mmol/L (tetany, death)**

▶ Red-top tube.

- 50% of calcium in blood is bound to albumin and is inactive; the other 50%, called free or ionized calcium, is metabolically active. Total calcium is a measurement of both bound and free calcium.
- Assess for diseases of the parathyroid gland or kidneys.

Carbon Dioxide Content (CO₂)

Adult: 22–30 mEq/L; SI units: 22–30 mmol/L

Child: 20–28 mEq/L; SI units: 20–28 mmol/L

▶ Red-top tube.

- Used in the evaluation of pH and electrolytes.
- Blood CO₂ measures the total amount of carbon dioxide in the blood (bicarbonate [HCO₃], dissolved carbon dioxide gas [CO₂], and carbonic acid [H₂CO₃]). It is essentially a measure of serum bicarbonate (HCO₃) because 95% of CO₂ is present as HCO₃.
- Do not confuse with PaCO₂, which measures the partial pressure of carbon dioxide.
- Increased: compensation for respiratory acidosis and metabolic alkalosis. Decreased: compensation for respiratory alkalosis and metabolic acidosis.

Carbon Monoxide (Carboxyhemoglobin)

Nonsmoker: <2%; Smoker: <9%; Toxic: >15%

Critical Levels: >20%

▶ Lavender-top tube.

- Used to evaluate patients exposed to smoke, fumes, and fires.
- Levels >20% cause dizziness and headache; >30%, tachycardia, hypotension, and confusion; >60%, coma and death.

Carcinoembryonic Antigen (CEA)

Nonsmokers: <3 ng/mL; SI units <3 μg/L

Smokers: <5 ng/mL; SI units <5 μg/L

▶ Red-top or lavender-top tube, depending on lab.

- Used to monitor treatment response and possible recurrence of breast, colon, or pancreatic cancer.
- Not a screening test since CEA can be elevated in benign diseases and smokers.
- Heparin use interferes with results. Hold for 2 days prior to test.

Cardiac Biomarkers

See individual tests for reference ranges.

- Enzymes, proteins, and hormones used in the diagnosis of acute myocardial infarction.
- Biomarkers rise, peak, and return to normal in predictable time frames allowing health care providers to monitor the progress of the infarction.
- These laboratory tests include:
 - ◆ Albumin cobalt binding
 - ◆ Creatinine kinase (CK) (or creatine phosphokinase) and CK-MB isoenzyme (less frequently used)
 - ◆ Troponin (most widely used to assess heart damage)
 - ◆ Myoglobin (less frequently used; may be ordered with troponin)
 - ◆ B-type natriuretic peptide (used to assess heart function)

Catecholamines and Vanillylmandelic Acid (VMA)

Adults

Epinephrine: 0–20 $\mu\text{g}/24\text{ hr}$; SI units: 0–109 nmol/day

Norepinephrine: 15–80 $\mu\text{g}/24\text{ hr}$; SI units: 89–473 nmol/day

Dopamine: 65–400 $\mu\text{g}/24\text{ hr}$; SI units: 424–2612 nmol/day

VMA: <6.8 mg/24 hr; SI units: <35 $\mu\text{mol}/24\text{ hr}$

Children

Epinephrine: 4–10 yrs: <10 $\mu\text{g}/24\text{ hr}$; SI units: <54.6 nmol/day

Norepinephrine: 4–10 yr: 8–65 $\mu\text{g}/24\text{ hr}$; SI units: 47–384 nmol/day

Dopamine: 1–4 yrs: 10–260 $\mu\text{g}/24\text{ hr}$; SI units: 65–1698 $\mu\text{mol}/\text{L}/\text{day}$

VMA: 2–18 yr: 1–5 mg/24 hr; SI units: <30 $\mu\text{mol}/24\text{ hr}$

▶ 24-hr urine collection.

- Used to screen for neuroendocrine tumors including pheochromocytoma.
- Test is affected by multiple foods and drugs. Check with lab about withholding medications or changing diet prior to and during the test.

Cerebrospinal Fluid Analysis (CSF Analysis)

Pressure: 50–180 mm H₂O

Appearance: Clear and colorless

Total protein: 15–45 mg/dL; SI units: 150–450 mg/L

Protein electrophoresis:

- ◆ Prealbumin: 2–7%
- ◆ Albumin: 56–76%
- ◆ Alpha₁ globulin: 2–7%
- ◆ Alpha₂ globulin: 4–12%
- ◆ Beta globulin: 8–18%
- ◆ Gamma globulin: 3–12%; SI units: 0.3–0.12
- ◆ Oligoclonal bands: none
- ◆ IgG: <3.4 mg/dL; SI units: <34 mg/L

Glucose: 50–80 mg/dL; SI units: 2.8–4.4 mmol/L

Cell count: 0–5 WBCs; no RBCs

Chloride: 118–132 mEq/L; SI units: 118–132 mmol/L

Lactate dehydrogenase: 10% of serum level

Lactic acid: 10–20 mg/dL; SI units: 1.1–2.2 mmol/L

Cytology: No malignant cells

Culture: No growth

Gram stain: Negative

India ink: Negative

VDRL: Nonreactive

Critical Values: Positive Gram's stain, India ink preparation, or culture.

- ▶ Sterile test tubes, numbered in the order they were filled. Send to lab immediately. Do not refrigerate.
 - Obtained by lumbar puncture, which requires careful patient preparation, postprocedure care, and informed consent.
 - Used to aid in the diagnosis of meningitis, intracranial or subarachnoid bleeding, brain injury, neurosyphilis, degenerative brain diseases, CNS cancer or metastases, autoimmune disorders, multiple sclerosis, and other conditions.

Chlamydia Group Antibody

Negative: <0.91; Equivocal: 0.91–1.09; Positive: >1.10

- ▶ Red-top tube.
 - Used in the diagnosis of chlamydial infection.
 - Detects IgG antibodies to *C. trachomatis*, *C. pneumoniae*, and *C. psittaci*.
 - Other methods, including swabs from infected areas for *C. trachomatis*, and urine samples are also used to detect *Chlamydia* infections.

Chloride (Cl)

Adult: 96–106 mEq/L; SI units: 96–106 mmol/L

Child: 90–110 mEq/L; SI units: 90–110 mmol/L

Critical levels: <80 mEq/L or >115 mEq/L

- ▶ Red-top or green-top tube.
 - Aids in maintenance of electrical neutrality, fluid and acid-base balance, and osmolality of body fluids (with sodium). Assessed with other electrolytes.
 - Decreased in vomiting, gastric suctioning, ketoacidosis, renal disease with loss of sodium.
 - Increased with diarrhea, dehydration, total parenteral nutrition.

Cholesterol, Total; High-density Lipoprotein Cholesterol (HDL, HDL-C); Low-density Lipoprotein Cholesterol (LDL, LDL-C); Very Low-density Lipoprotein (VLDL)
Total Cholesterol

Adult: <200 mg/dL; SI units: <5.2 mmol/L

Child: 125–200 mg/dL; SI units: 3.27–5.2 mmol/L

HDL Cholesterol

Adult: >50 mg/dL; SI units: >1.40 mmol/L

LDL Cholesterol

Adult: <100 mg/dL; SI units: <2.56 mmol/L

VLDL Cholesterol

25–50%

- ▶ Red-top tube. Fasting sample; no alcohol for 24 hr prior to test.
 - Blood lipids synthesized in the liver and integral to the formation of cell membranes, bile salts, and hormones.
 - Implicated in atherosclerosis and MI.
 - HDL levels >60 mg/dL are protective against heart disease.

Coagulation Factors

- ◆ Factor II (prothrombin)
- ◆ Factor V (proaccelerin or labile factor)
- ◆ Factor VII (proconvertin or stable factor)
- ◆ Factor VIII (antihemophilic factor A, antihemophilic globulin)
- ◆ Factor IX (antihemophilic factor B, plasma thromboplastin component, Christmas factor)
- ◆ Factor X (Stuart-Prower factor)
- ◆ Factor XI (plasma thromboplastin antecedent)
- ◆ Factor XII (Hageman factor)

One-stage Assay: Intrinsic Coagulation System

Factor VIII: 55–145% of control

Factor IX: 60–140% of control

Factor XI: 65–135% of control

Factor XII: 50–150% of control

One-stage Assay: Extrinsic Coagulation System

Factor II: 50–200% of control

Factor V: 50–150% of control

Factor VII: 65–135% of control

Factor X: 45–155% of control

► Blue-top tube.

- Coagulation is a cascade of events involving over 30 different substances. It causes circulating substances within the blood to coagulate into a gel, forming a protective barrier over injured body tissues or blood vessels.
- Although the completion of clotting follows a common path, clotting can be initiated by either the *intrinsic* or the *extrinsic* pathway. Both pathways are usually triggered in tissue or blood vessel injury; however, in hemophilic diseases, alterations in intrinsic factors cause the bleeding disorder. In DIC, multiple clotting factor abnormalities occur.
- In addition to the above eight factors, **tissue factor (tissue thromboplastin)** released by damaged cells, thrombin, fibrinogen, and calcium are integral to clot formation.
- Clotting factors are assessed to determine the cause of bleeding disorders. Fibrin degradation products, D-dimers, and plasminogen are also measured in coagulopathies and represent the process of clot dissolution or the fibrinolytic system.

Cold Agglutinin Titer

Negative (<1:16)

- ▶ Red-top tube. Do not refrigerate.
 - Cold agglutinins are antibodies that cause red blood cells to agglutinate (clump together).
 - Used in the diagnosis of primary atypical pneumonia, *Mycoplasma pneumoniae*, hemolytic anemia, gangrene, Raynaud's disease, and other diseases.

Complement, Total

Adult: 75–160 U/mL; SI units: 75–160 kU/L

- ▶ Red-top tube.
 - Proteins involved in immunological and inflammatory responses.
 - Diagnose angioedema; assess treatment/status of various diseases including systemic lupus erythematosus nephritis and other types of nephritis.
 - Deficiency associated with increased susceptibility to infection.

Complement C3 and C4

C3: 55–120 mg/dL; SI units: 0.55–1.2 g/L

C4: 20–50 mg/dL; SI units: 0.2–.05 g/L

- ▶ Red-top tube.
 - Commonly assessed components of the complement system.
 - Increased levels associated with rheumatoid arthritis, some cancers, and acute viral hepatitis.
 - Decreased levels associated with SLE, glomerulonephritis, DIC, gram-negative sepsis.

Complete Blood Count with Differential (CBC with diff)

Test	Conventional	SI Units
Red Blood Cell (RBC)	Male: $4.6\text{--}6.2 \times 10^6$ cells / μL	$4.6\text{--}6.2 \times 10^{12}$ cells /L
	Female: $4.2\text{--}5.9 \times 10^6$ cells / μL	$4.2\text{--}5.9 \times 10^{12}$ cells /L
Hemoglobin (Hgb)	Male: 13–18 g/dL	Male: 130–180 g/L
	Female: 12–16 g/dL	Female: 120–160 g/L
Hematocrit (Hct)	Male: 45–52%	Male: 0.45–0.52
	Female: 37–48%	Female: 0.37–0.48
MCV	80 to 100 μm^3	80 to 100 μm^3
MCH	27 to 31 pg/cell	27 to 31 pg/cell
MCHC	32 to 36 g/dL	32 to 36 g/dL
White Blood Cells (WBC)	4,300–10,800 cells/ mm^3	$4.3\text{--}10.8 \times 10^9/\text{L}$
<i>WBC Differential</i>		
◆ Neutrophils, bands	0–5%	0.03–0.08
◆ Neutrophils, segmented	54–65%	0.54–0.65
◆ Lymphocytes	25–40%	0.25–0.40
◆ Monocytes	2–8%	0.02–0.08
◆ Eosinophils	1–4%	0.010.04
◆ Basophils	0–1%	0–0.01
Platelets	150,00–450,000/ mm^3	$150\text{--}450 \times 10^9/\text{L}$

Critical levels:**Hgb:** <5 g/dL or >20 g/dL**Hct:** <15% or >60%**WBC:** <500 mm^3 or >50,000/ mm^3 **Platelets:** <50,000 or >999,000/ mm^3

▶ Lavender-top tube.

■ A CBC reveals

- ◆ Information about general health.
- ◆ Number of red blood cells (RBC).

- ◆ Number of white blood cells (WBC) and differential (see White Blood Cells for more information).
- ◆ Total amount of hemoglobin in the blood (Hgb).
- ◆ Fraction of blood composed of red blood cells (Hct).
- ◆ Volume of Hgb in each RBC (MCV [mean corpuscular volume]).
- ◆ Weight of the Hgb in each RBC (MCH [mean corpuscular hemoglobin]).
- ◆ Proportion of Hgb contained in each RBC (MCHC [mean corpuscular hemoglobin concentration]).
- ◆ Number of platelets, which are critical to clot formation (see Platelets for more information).
- MCV, MCH, and MCHC values are useful in the diagnosis of various types of anemia. See below for description of anemias.

Types of Anemia

Type of Anemia	Possible Causes
Normocytic/normochromic (normal cell size; normal amount of Hgb)	Acute blood loss, aplastic anemia, prosthetic heart valves, sepsis, tumor
Microcytic/hypochromic (small cell size; low amount of Hgb)	Iron deficiency, lead poisoning, thalassemia
Microcytic/normochromic (small cell size; normal amount of Hgb)	Erythropoietin deficiency secondary to renal failure
Macrocytic/normochromic (large cell size; normal amount of Hgb)	Chemotherapy, folate deficiency, vitamin B ₁₂ deficiency

Terms

- ◆ Microcytic— MCV less than normal (<80 fL)
- ◆ Normocytic— MCV within normal range (80–100 fL)
- ◆ Macrocytic— MCV greater than normal (>100 fL)
- ◆ Hypochromic—MCH less than normal (<27 pg)
- ◆ Normochromic—MCH within normal range (27–31 pg)
- ◆ Hyperchromic—MCH greater than normal (>31 pg)

Coombs' Test, Direct (Direct Antiglobulin)

Negative; no agglutination

- ▶ Lavender-top tube.
 - Assess for immunoglobulins (antibodies) on surface of red blood cells
 - Positive results occur in hemolytic transfusion reactions, hemolytic anemias, erythroblastosis fetalis

Coombs' Test, Indirect (Indirect Antiglobulin, Autoantibody Test)

Negative

- ▶ Red-top tube.
 - Part of a cross-match for blood transfusion.
 - Positive result indicates incompatibility.

Cortisol, FreeAdult: <50 $\mu\text{g}/24$; SI units: <138 nmol/dayChild: <38 $\mu\text{g}/24$ hr; SI units: <104 nmol/day

- ▶ 24-hr urine collection.
 - Used to screen for adrenal hyperfunction.
 - Result from urinary free cortisol test is a better indication of cortisol secretion than a single plasma level.
 - Best test for diagnosing Cushing's syndrome.

Cortisol, PlasmaAdult: 8 AM–10 AM: 5–23 $\mu\text{g}/\text{dL}$; SI units: 138–635 mmol/L.4 PM–6 PM: 3–13 $\mu\text{g}/\text{dL}$; SI units: 83–359 mmol/LChild: 8 AM–10 AM: 15–25 $\mu\text{g}/\text{dL}$ 4 PM–6 PM: 5–10 $\mu\text{g}/\text{dL}$

- ▶ Green-top tube.
 - Powerful glucocorticoid secreted by the adrenal cortex in response to ACTH. Higher in the morning.
 - Affects gluconeogenesis, fat and protein metabolism; aids in regulation of immune system; is increased during physical or emotional stress.
 - Assessed in the evaluation of Cushing's syndrome and Addison's disease.

***Creatinine Phosphokinase, (CPK, Creatine Kinase, CK);
CPK Isoenzymes*****CPK**

Adult: *Male:* 55–170 U/L; SI units: 55–170 U/L. *Female:* 30–135 U/L;

SI units: 30–135 U/L

Newborn: 68–580 U/L

Isoenzymes

CPK-MM: 100%; CPK-MB: 0%; CPK-BB: 0%

▶ Red-top tube.

- CPK is an enzyme critical to intracellular energy.
- The MB isoenzyme is a cardiac marker (but is not as specific as troponin). Elevations occur in acute MI and are used in the diagnosis of MI.
- CPK-MB ratio to total CPK is calculated to increase diagnostic accuracy. A ratio of 2.5 correlates with cardiac damage.
- MM elevations occur in crush injuries, seizures, malignant hypothermia.

Creatinine, Serum

Adult: *Male:* 0.6–1.2 mg/dL; SI units: 53–106 μ mol/L. *Female:* 0.5–1.1 mg/dL; SI units: 44–97 μ mol/L

Child: 0.3–0.7 mg/dL

▶ Red-top tube.

- Breakdown product of creatine phosphate in muscle.
- Produced at a constant rate by the body and excreted by the kidney. Blood level rises in renal impairment.
- Creatinine level is a sensitive indicator of renal function but is dependent on kidney function and muscle mass. Patients with decreased muscle mass do not exhibit a rise in creatinine levels as readily as those with more muscle mass and should have an estimated glomerular filtration rate (GFR) reported as well.

Creatinine, Urine

1–2 g/24 hr; SI units: 8.8–17.7 mmol/day

▶ 24-hr urine collection. Refrigerate.

- Creatinine is a by-product of muscle breakdown. It is filtered (removed from plasma) by the kidneys and excreted in the urine.
- Elevated levels of creatinine indicate impaired renal function.

Creatinine Clearance

Male: 107–139 mL/min; SI units: 1.78–2.32 mL/s. *Female:* 85–105 mL/min; SI units: 1.45–1.78 mL/s.

- ▶ Timed urine sample (12 or 24 hr) with a blood sample taken the morning of or sometime during the test.
 - Creatinine clearance refers to the amount of blood that can be cleared of creatinine in 1 min.
 - It is calculated using the volume of urine, the amount of creatinine excreted, and the amount of creatinine in the blood.
 - It is used to determine safe dosing of nephrotoxic drugs. Creatinine clearance of 10–20 mL/min is indicative of renal failure and the need for dialysis.

Cryoglobulins

< 0.4% or none detected

- Abnormal proteins present in various immune, hematologic, collagen vascular, and oncologic disorders.
- Levels >5 mg/mL are associated with multiple myeloma and leukemia.
- Levels between 1 and 5 mg/mL are associated with rheumatoid arthritis.

Cystatin C

Adult: 0.5–1 mg/L

Child: 0–3 mo: 0.8–2.3 mg/L; 4–11 mo: 0.7–1.5 mg/L;
1–17 yr: 0.5–1.3 mg/L

- ▶ Red-top tube.
 - A cysteine protease inhibitor that is freely filtered (removed) by the glomeruli and thus can be used to assess for changes in glomerular filtration rate.
 - High levels of cystatin C suggest impaired renal function.
 - It is thought to be superior to creatinine as a marker of glomerular filtration rate because it is not affected by muscle mass, diet, or acute inflammatory processes.

Cystine

10–100 mg/24 hr

- ▶ 24-hr urine collection.
 - Used to detect cystinuria or identify cause of kidney stones.

Cytomegalovirus (CMV) Antibodies

IgM < 1:8; IgG < 1:16

- ▶ Red-top tube.
 - CMV is a virus in the herpes family.
 - Active infection significant in pregnant women, potential transplant patients and immunocompromised patients.
 - If active infection is suspected, a second sample is assessed in 10–14 days.

D-dimers

Negative (<250 ng/mL; SI units: <250 µg/L)

- ▶ Blue-top tube.
 - A fibrin degradation product produced only after a clot has formed and is in the process of being broken down.
 - Used in the diagnosis of deep vein thrombosis (DVT), pulmonary embolism (PE), or disseminated intravascular coagulation (DIC).

Dexamethasone Suppression Test**Low Dose**

Overnight: 8 AM plasma cortisol: <5 µg/dL

Standard: Urinary free cortisol on day 3: <10 µg/day

High Dose

Overnight: >50% reduction in plasma cortisol.

Standard: >90% reduction in urinary free cortisol.

- ▶ Red-top tube.
 - Administration of dexamethasone suppresses ACTH and should suppress cortisol levels in healthy people.
 - Helpful in determining cause of increased cortisol levels (adrenal tumor, pituitary tumor, or ectopic ACTH-producing tumor).

Drug Levels, Therapeutic and Toxic
Conventional (US System of Measurements)

Drug	Therapeutic Level	Toxic Level
acetaminophen	5–20 µg/mL	>40 µg/mL
alprazolam	10–50 ng/mL	>75 ng/mL
amikacin	peak: 20–30 µg/mL trough: 4–8 µg/mL	peak: >35 µg/mL trough: >10 µg/mL
aminocaproic acid	100–400 µg/mL	>400 µg/mL
aminophylline	10–20 µg/mL	>20 µg/ml
amiodarone	0.5–2.5 µg/mL	>2.5 µg/mL
amitriptyline	120–150 ng/mL	>500 ng/ml
amoxapine	200–400 ng/mL	>500 ng/mL
atenolol	200–500 ng/mL	>500 ng/mL
bepidil HCl	1–2 ng/mL	>2 ng/mL
carbamazepine	5–12 µg/mL	>12 µg/mL
chloral hydrate	2–12 µg/mL	>20 µg/mL
chloramphenicol	10–20 µg/mL	>25 µg/mL
chlordiazepoxide	1–5 µg/mL	>5 µg/mL
chlorpromazine	50–300 ng/mL	>750 ng/mL
chlorpropamide	75–250 µg/mL	>250 µg/mL
clonazepam	15–60 ng/mL	>80 ng/mL
cyclosporine	100–300 ng/mL	<85 or >500 ng/mL
desipramine	150–300 ng/mL	>500 ng/mL
diazepam	0.5–2 mg/L	>3 mg/L
digoxin	0.8–2 ng/mL	>2 ng/mL
diltiazem	50–200 ng/mL	>200 ng/mL
disopyramide	2–5 µg/mL	>7 µg/mL
doxepin	150–300 ng/mL	>400 ng/mL
ethosuximide	40–100 µg/mL	>150 µg/mL
flecainide	0.2–1 µg/mL	>1 µg/mL
gentamicin	peak: 6–10 µg/mL trough: < 2 µg/mL	peak: >12 µg/mL trough: >2 µg/mL

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Drug	Therapeutic Level	Toxic Level
haloperidol	3–20 ng/mL	>42 ng/mL
hydromorphone	1–30 ng/mL	>100 ng/mL
imipramine	150–300 ng/mL	>500 ng/mL
kanamycin	20–25 µg/mL	>35 µg/mL
lidocaine	1.5–5 µg/mL	>5 µg/mL
lithium	0.5–1.5 mEq/L	>1.5 mEq/L
meperidine	0.4–0.7 µg/mL	>1 µg/mL
methotrexate	> 0.01 µmol	>10 µmol in 24 hr
mexiletine	0.5–2 µg/mL	>2 µg/mL
mezlocillin sodium	35–45 µg/mL	>45 µg/mL
milrinone	150–250 ng/mL	>250 ng/mL
morphine	10–80 ng/mL	>200 ng/mL
nicardipine	0.028–0.05 µg/mL	>0.05 µg/mL
nifedipine	0.025–0.1 µg/mL	>0.1 µg/mL
nortriptyline	50–150 ng/mL	>500 ng/mL
phenobarbital	15–30 µg/mL	>40 µg/mL
phenytoin	10–20 µg/mL	>20 µg/mL
primidone	5–12 µg/mL	>12 µg/mL
procainamide	4–10 µg/mL	>10 µg/mL
propafenone	0.5–3 µg/mL	>3 µg/mL
propranolol	50–100 ng/mL	>150 ng/mL
quinidine	2–5 µg/mL	>6 µg/mL
salicylate	10–30 mg/dL	>35 mg/dL
theophylline	10–20 µg/mL	>20 µg/mL
tobramycin	peak: 6–10 µg/mL	peak: >12 µg/mL
	trough: < 2 µg/mL	trough: >2µg/mL
tocainide HCl	4–10 µg/mL	>12 µg/mL
trazadone	500–2000 ng/mL	>4000 ng/mL
valproic acid	50–100 µg/mL	>100 µg/mL
vancomycin	peak: 20–40 µg/mL	peak: >80 µg/mL
	trough: 5–10 µg/mL	trough: >10 µg/mL
verapamil	0.08–0.3 µg/mL	>0.3 µg/mL

SI Units (International System of Units)

Drug	Therapeutic Range	Toxic Level
amikacin	peak: 34–51 $\mu\text{mol/L}$ trough: 7–14 $\mu\text{mol/L}$	peak: >60 $\mu\text{mol/L}$
amitriptyline	433–903 nmol/L	>805 nmol/L
carbamazepine	21–51 $\mu\text{mol/L}$	>51 $\mu\text{mol/L}$
clonazepam	40–200 nmol/L	>260 nmol/L
desipramine	281–1125 nmol/L	>1500 nmol/L
diazepam	0.35–3.5 nmol/L	>17.5 nmol/L
digoxin	1–2.6 nmol/L	>2.6 nmol/L
disopyramide	9–18 $\mu\text{mol/L}$	> 21 $\mu\text{mol/L}$
ethosuximide	280–708 $\mu\text{mol/L}$	>1062 $\mu\text{mol/L}$
flecainide	0.5–2.4 $\mu\text{mol/L}$	>2.4 $\mu\text{mol/L}$
gentamicin	peak: 12–21 $\mu\text{mol/L}$ trough: <4 $\mu\text{mol/L}$	peak: >21 $\mu\text{mol/L}$
imipramine	610–1670 nmol/L	>1785 nmol/L
lignocaine	6–21 $\mu\text{mol/L}$	>39 $\mu\text{mol/L}$
lithium	0.5–1.5 mmol/L	>2 mmol/L
nortriptyline	190–570 nmol/L	>1900 nmol/L
phenobarbitone	86–172 $\mu\text{mol/L}$	>172 $\mu\text{mol/L}$
phenytoin	40–80 $\mu\text{mol/L}$	>158 $\mu\text{mol/L}$
primidone	23–55 $\mu\text{mol/L}$	>55 $\mu\text{mol/L}$
procainamide	17–42 $\mu\text{mol/L}$	>51 $\mu\text{mol/L}$
quinidine	6–15 $\mu\text{mol/L}$	>29 $\mu\text{mol/L}$
salicylic acid	1–2 mmol/L	>3.6 mmol/L
theophylline	28–111 $\mu\text{mol/L}$	>111 $\mu\text{mol/L}$
tobramycin	peak: 13–21 $\mu\text{mol/L}$ trough: < 4 $\mu\text{mol/L}$	peak: >21 $\mu\text{mol/L}$
valproic acid	350–700 $\mu\text{mol/L}$	>1386 $\mu\text{mol/L}$
vancomycin	peak: 14–28 $\mu\text{mol/L}$ trough: 3–7 $\mu\text{mol/L}$	peak: >28 $\mu\text{mol/L}$

- ▶ Red-top tube.
 - Drug levels are obtained both to enhance therapeutic efficacy and to assess for toxicity/overdose/poisoning.
 - **Therapeutic drug monitoring (TDM)** is the measurement of serum drug levels so that dosages may be adjusted to achieve optimum clinical benefit.
 - Therapeutic drug monitoring is used with
 - ◆ cardiac glycosides (e.g., digoxin)
 - ◆ antiarrhythmics (e.g., lidocaine, procainamide)
 - ◆ anticonvulsants (e.g., phenytoin, carbamazepine)
 - ◆ lithium
 - ◆ theophylline
 - ◆ aminoglycoside antibiotics (gentamicin, tobramycin)
 - ◆ salicylates
 - For TDM, blood samples must be obtained at the appropriate time and after sufficient number of doses have been administered for valid interpretation of results.
 - Peak and trough levels are drawn with some drugs, especially antibiotics. Peak levels are drawn at the point of maximum drug absorption; trough levels are drawn just before the next dose.

Electrolytes, Serum

See individual tests for normal values.

- ▶ Red-top tube.
 - Electrolytes are minerals present in body tissues and blood as dissolved salts.
 - They are electrically charged particles that help maintain fluid and acid-base balance. They help move nutrients into cells and waste products out.
 - An electrolyte panel measures sodium (Na^+), potassium (K^+), chloride (Cl^-), and bicarbonate (HCO_3^-), which is measured indirectly as CO_2 .
 - See individual tests and Anion Gap for more information.

Electrolytes, Urine

	Conventional Units	SI Units
Sodium	30–280 mEq/day	30–280 mmol/day
Chloride	110–250 mEq/day	110–250 mmol/day
Potassium	40–80 mEq/day	40–80 mmol/day
Calcium	<i>Male:</i> <275 mg/day; <i>Female:</i> <250 mg/day	<i>Male:</i> <6.8 mmol/day; <i>Female:</i> <6.2 mmol/day
Phosphorus	0.9–1.3 g/day	29–42 mmol/day
Magnesium	<150 mg/day	3–4.3 mmol/day

▶ 24-hour urine collection

- Provides information about hydration status, the kidneys' ability to conserve or excrete sodium.
- Calcium levels are increased in hyperthyroidism, immobilization, multiple myeloma, Paget's disease, and bone metastases.

Erythropoietin (EPO)

5–35 IU/L

▶ Red-top tube.

- Hormone produced by the kidney to stimulate RBC production.
- Decreased in patients with renal disease, primary polycythemia.

Estradiol, Serum (Estrogen Fraction)

Adult: *Female:* Follicular phase: 20–150 pg/mL; Midcycle phase: 100–500 pg/mL; Luteal phase: 60–260 pg/mL; *Pregnancy:* 1st tri: 1–5 ng/mL; 2nd tri: 5–15 ng/mL; 3rd tri: 10–40 ng/mL; *Postmenopause:* <30 pg/mL. *Male:* 15–50 pg/mL

▶ Red-top tube.

- An estrogen fraction useful in evaluating fetal well-being, menstrual and fertility problems in women, precocious puberty in girls, gynecomastia.
- Used to assess amenorrhea to determine if cause is menopause, pregnancy, or a medical problem.
- Serial measurements are used to monitor follicle development in the ovary prior to in vitro fertilization.
- **Estrone**, the major estrogen after menopause, and **estriol**, the major estrogen in pregnant women, are the other major estrogens.

Ethanol (blood alcohol)

None

- ▶ Red-top tube. Use povidone-iodine swab not alcohol to clean venipuncture site.
 - Levels $>0.8\%$ are considered to be proof of intoxication in most states.

Febrile Agglutinin TiterNegative ($<1:80$)

- ▶ Red-top tube. Do not warm.
 - Febrile agglutinins are antibodies that cause RBCs to agglutinate (clump together) at high temperatures.
 - Febrile agglutinin titers are used in the diagnosis of some bacterial infections (salmonellosis, tularemia, Rocky Mountain spotted fever, typhus, brucellosis).

Fecal Fats (Fecal Lipids)

2–6 g/24 hr; SI units: 7–21 mmol/day

- ▶ 72-hr stool collection. Keep refrigerated during collection.
 - Assist in the diagnosis of malabsorption or pancreatic insufficiency.
 - A high fat diet should be eaten for 3 days before and throughout the collection time period and should refrain from laxative use.

Fecal Occult Blood (FOB, Stool for Occult Blood)

Negative

- ▶ Stool sample
 - Used to detect microscopic bleeding into the GI tract.
 - Routine screening test for patients over 50 years old.
 - Positive in ulcers, polyps, hemorrhoids, tumors, inflammatory bowel disease, diverticulosis, and other disorders of the GI tract.

FerritinAdult: *Female*: 10–150 ng/mL; SI units: 10–150 $\mu\text{g/L}$. *Male*: 12–300 ng/mL; SI units: 12–300 $\mu\text{g/L}$ Child >1 year: 7–140 ng/mL; SI units: 7–140 $\mu\text{g/L}$

- ▶ Red-top tube.
 - Indicates available iron stores in the body.
 - Level below 10 ng/mL diagnostic of iron deficiency anemia.

Fibrin Split Products (Fibrin Degradation Products, FDP, FSP)

<5 $\mu\text{g/mL}$; SI units: <5 mg/L

- ▶ Blue-top tube (check with lab).
 - Blood clots in the vascular system stimulate the production of plasmin, which breaks down clots into fibrin split products.
 - Elevated amounts of fibrin split products in the blood indirectly indicate the presence of blood clots or a fibrinolytic disorder such as DIC.

Fibrinogen

150–400 mg/dL; SI units: 1.5–4 g/L

Critical Levels: <100 mg/dL

- ▶ Blue-top tube.
 - Fibrinogen is essential to clot formation. Decreased fibrinogen levels result in prolonged PT and PTT.
 - Useful in diagnosis of DIC.

Folic Acid (Folate)

> 2 ng/mL (radioimmunoassay); SI units: >5 mmol/L

- ▶ Red-top tube.
 - Normal levels essential for properly functioning red and white blood cells.
 - Decreased in malabsorption, malnutrition, liver disease, cancer.

Follicle-stimulating Hormone (FSH)

Adult: *Males:* 5–15 IU/L. *Females:* follicular or luteal phase: 5–20 IU/L, midcycle: 30–50 IU/L, postmenopause: >50 IU/L.

Prepubertal children: <6 IU/L

- ▶ Red-top tube.
 - Pituitary hormone involved in maturation of ovarian follicle in women and spermatogenesis in men.

Gamma-Glutamyl Transpeptidase (GGT, SGGT)Adult: *Male:* 9–50 IU/L. *Female:* 8–40 IU/L

- ▶ Red-top tube.
 - Liver enzyme sensitive to biliary and liver disorders, including alcoholic liver disease.

Gastrin

Fasting: <100 pg/mL; SI units: 47.7 pmol/L

Postprandial: 95–140 pg/mL; SI units: 45.3–66.7 pmol/L

- ▶ Red-top tube.
 - Hormone that stimulates secretion of gastric acid.
 - Elevated in pernicious anemia, Zollinger-Ellison syndrome, stomach cancer, peptic ulcer, atrophic gastritis, renal insufficiency, steroid administration, H₂ blockers.

Glucagon

Adult: 50–100 pg/mL; SI units: 50–100 ng/L

Child: 0–148 pg/mL; SI units: 0–148 ng/L

- ▶ Lavender-top tube, chilled. Fasting sample.
 - Hormone secreted by the alpha cells of the islets of Langerhans.
 - Glucagon deficiency may occur with pancreatitis, pancreatic cancer, cystic fibrosis.
 - Elevated glucagon levels occur with glucagonoma (cancer of the alpha islet cells), diabetes, acute pancreatitis, cirrhosis, stress, renal failure, rejection of transplanted kidney.

Glucose, Fasting

Adult: 70–105 mg/dL; SI units: 3.9–5.8 mmol/L

Child < 2 years old: 60–100 mg/dL

Critical Levels: <50 or >400 mg/dL

- ▶ Red-top tube. Fasting sample.
 - Assessed to diagnose or monitor Type 1 and 2 diabetes.
 - An elevated fasting blood glucose level above 126 mg/dL on at least two occasions typically indicates diabetes.

Glucose-6-Phosphate Dehydrogenase (G-6-PD) Screening Test and G-6-PD Assay

Screening Test

Negative

Assay

7.0–20.5 U/g of hemoglobin; SI units: 0.45–1.29 mU/mol (reference ranges vary with testing methodology)

- ▶ Lavender- or green-top tube.
 - G-6-PD is an enzyme found in RBCs; its function is to protect hemoglobin from oxidation.
 - People with a G-6-PD deficiency are susceptible to hemolysis when exposed to an oxidative stressor such as systemic infections, septicemia, metabolic acidosis, and exposure to oxidant drugs (aspirin, sulfa drugs, antimalarials, thiazide diuretics, quinidine, antipyretics, sulfanomides, chloramphenicol, phenacetin, probenecid, and tolbutamide).

Glucose Tolerance Test, Standard Oral

Fasting: <126 mg/dL; SI units: <7 mmol/L

2-hr: <200 mg/dL; SI units <1.1 mmol/L

- ▶ Red-top tube. Fasting sample.
 - Blood glucose levels are assessed twice. The first is a fasting sample, the second sample is taken 2 hr after ingestion of 75 g of glucose. Samples may be assessed at other times as well.
 - Useful for screening for gestational diabetes but usually unnecessary for diagnosing diabetes as fasting blood glucose >126 mg/dL or a random blood glucose level >200 mg/dL is usually considered diagnostic.

Glycosylated Hemoglobin (A1C, GHb, Glycohemoglobin, HBA₁)

Nondiabetic: < 5%

Diabetes well controlled: 2.5–6%

Diabetes not well controlled: > 8%

- ▶ Lavender-top tube.
 - Prolonged blood glucose elevation causes a greater percentage of RBCs to become saturated with glucose (glycohemoglobin).
 - Used for monitoring average diabetic control for preceding 3 months as blood cells typically live for 2–3 months.

- Assessed two times per year for patients with type 2 diabetes not on insulin and four times per year for patients with type 1 or 2 diabetes on insulin.

Growth Hormone (GH, Human Growth Hormone [HGH], Somatotropin Hormone [SH]), Growth Hormone Suppression Test, and Growth Hormone Stimulation Test

Adult: *Males:* <5 ng/mL; SI units: <5 µg/L. *Females:* <10 ng/mL; SI units: <10 µg/L

Children: 0–10 ng/mL; SI units: 0–10 µg/L

Newborns: 10–40 ng/mL; SI units: 10–40 µg/L

▶ Red-top tube.

- Growth hormone is produced in episodic bursts by the pituitary gland.
- Assessed to evaluate possible dwarfism, growth retardation, or gigantism in children and acromegaly in adults.

Haptoglobin

Adult: 60–270 mg/dL; SI units: 0.6–2.7 g/L

Newborn: 0–10 mg/dL; SI units: 0–0.1 g/L

▶ Red-top tube.

- A protein produced by the liver that binds to hemoglobin when it is released from hemolyzed RBCs.
- Increased in many inflammatory diseases.
- Decreased in hemolytic conditions (e.g., transfusion reaction, anemia), hepatic disease.

Helicobacter pylori Antibody Titers

Negative

▶ Red-top tube.

- Organism associated with gastric ulcer and gastritis.
- Also may be assessed by culture, biopsy, or breath test.

Hematocrit (Hct)

Adult: *Male:* 45–52%; SI units: 0.45–0.52. *Female:* 37–48%; SI units: 0.37–0.48.

Child: 1–6 yr: 30–40%; SI units: 0.30–0.40; 6–18 yrs: 32–44%; SI units: 0.32–0.44

Critical Levels: <15% or >60%

▶ Lavender-top tube.

- Hematocrit is the percentage of whole blood that is made up of red blood cells. It is expressed as a percentage or a decimal fraction. (A hematocrit value of 35% means that there is 35 mL of red blood cells in 100 mL of blood.)
- Increased in dehydration and increased production of RBCs.
- Decreased in anemia, when RBC production is impaired or there is increased destruction of RBCs, in chronic disease, blood loss, and fluid volume excess.
- See Complete Blood Count.

Hemoglobin (Hgb)

Adult: *Male*: 14–18 g/dL; SI units: 8.7–11.2 mmol/L. *Female*: 12–16 g/dL; SI units: 7.4–9.9 mmol/L.

Child: 1–14 ys: 11.3–14.4 g/dL; SI units: 113–144 mmol/L.

Critical Levels: <5 or >20 g/dL

▶ Lavender-top tube.

- Hemoglobin is the main protein in erythrocytes. It carries oxygen to and removes carbon dioxide from red blood cells.
- Increased in dehydration, COPD, high altitudes, polycythemia vera.
- Decreased in fluid volume excess, hematologic cancers, hemolytic disorders, blood loss, anemia.
- See Complete Blood Count.

Hemoglobin Electrophoresis (Hemoglobinopathy Profile)

Hgb A₁: 95–98%

Hgb A₂: 2–3%

Hgb F: 0.8–2%; *Newborn*: 50–80%; > 6 mo old: 1–2%

Hgb C, S, or E: 0%

▶ Lavender-top tube.

- Used to screen for abnormal hemoglobins.
- Hemoglobin A, A₂ and F are normal hemoglobins. Hgb F is the predominant fetal hemoglobin.
- Hgb S is the predominant hemoglobin found in people with sickle cell disease.
- Hgb C and Hgb E produce mild hemolytic anemia and splenomegaly. They are considered relatively benign. Hgb E is extremely common in Southeast Asia.

Hepatitis Testing

Negative

- ▶ Red-top tube.
 - Screening for hepatitis A, B, C, D, or E.
 - May test for antigens, antibodies, IgG, or IgM (immunoglobulins).
 - Viral hepatitis serologic testing patterns need to be interpreted to determine if disease is active, acute, chronic, or historical (carrier state).

Hexosaminidase, Total, A, A and B (Hex A)**Total Hexosaminidase**

Noncarrier: 589–955 nmol/hr/mL; SI units: 9.9–15.9 U/L

Heterozygote: 465–675 nmol/hr/mL; SI units: 7.8–11.3 U/L

Tay-Sachs homozygote: >1027 nmol/hr/mL; SI units: >17.2 U/L

Hexosaminidase A

Noncarrier: 456–592 nmol/hr/m; SI units: 7.2–9.9 U/L

Heterozygote: 197–323 nmol/hr/mL; SI units: 3.3–5.39 U/L

Tay-Sachs homozygote: 0 nmol/hr/mL; SI units: 0 U/L

Hexosaminidase B

Noncarrier: 12–32 nmol/hr/mL; SI units: 0.2–0.54 U/L

Heterozygote: 21–81 nmol/hr/mL; SI units: 0.35–1.35 U/L

Tay-Sachs homozygote: >305 nmol/hr/mL; SI units: >5.1 U/L

- ▶ Red-top tube
 - Hexosaminidase is an enzyme necessary for metabolism of gangliosides. Deficiency results in accumulation of gangliosides in the brain.
 - Used to diagnose Tay-Sachs disease, which is caused by a lack of hexosaminidase A and results in mental retardation, blindness, weakness, and death by age 5.
 - Sandhoff's disease is a variant of Tay-Sachs and results from a deficiency of both hexosaminidase A and B.

High-density Lipoprotein Cholesterol

See Cholesterol.

Homocysteine

4–17 μ mol/L

- ▶ Red-top tube
 - Elevated levels are a risk factor for coronary artery disease.
 - Increased in renal failure and secondary to some medications.

Human Chorionic Gonadotropin, Serum (HCG)

Nonpregnant state: < 0.01 IU/mL

4 weeks pregnant: 0.10–1.0 IU/mL

16 weeks pregnant: 10–50 IU/mL

- ▶ Red-top tube.
 - Hormone produced by the placenta.
 - Levels peak at about 16 weeks and then decline.

Human Immunodeficiency Virus (HIV) Testing

HIV Antibody, ELISA: negative

HIV Western Blot: negative

HIV Antigen (P-24 Antigen): negative

HIV Viral load: <50 copies/mL

- ▶ Red-top tube.
 - Used to diagnose HIV infection.
 - Viral load tests are used to inform treatment strategies and monitor disease progression.

Human Leukocyte Antigens (HLA)

Match or nonmatch

- ▶ Green-top tube.
 - Used to assess tissue compatibility.
 - Useful in assessing compatibility for organ transplants.

5-Hydroxyindoleacetic Acid

2–8 mg/24 hr; SI units: 10.4–41.6 mmol/24 hr

- ▶ 24-hr urine collection.
 - Used in the diagnosis of carcinoid tumors (a tumor found in the appendix or intestinal wall that secretes high levels of serotonin leading to symptoms including hypertension, facial flushing, abdominal cramps, and heart valve damage).
 - Certain foods and medications must be avoided before urine collection. These include: bananas, pineapple, red plums, avocado, walnuts, kiwi, tomatoes, cough medicines, muscle relaxants, acetaminophen, caffeine, fluorouracil, iodine solutions, phenacetin, MAO inhibitors, isoniazid, and phenothiazine drugs such as Compazine and Thorazine.

Immunoglobulins

IgG (>10 years old): 650–1700 mg/dL; SI units: 6.5–17 g/L

IgA (>10 years old): 40–390 mg/dL; SI units: 0.40–3.90 g/L

IgM (>2 years old): 25–210 mg/dL; SI units: 0.25–2.1 g/L

IgD (Adults): 0.5–3 mg/dL; SI units: 0.005–0.03 g/L

IgE (Adults): 0.01–0.04 mg/dL; SI units: 0–430 mg/L

▶ Red-top tube.

■ Used to evaluate immunity.

■ Monitor other diseases such as multiple myeloma, lymphoma, bacterial infection, malnutrition, sarcoidosis.

International Normalized Ratio (INR)

See Prothrombin Time.

Iron Tests (Serum Iron, Total Iron Binding Capacity, Serum Transferrin, Transferrin Saturation)**Serum Iron**

Adult: 35–165 $\mu\text{g/dL}$; SI units: 10–27 $\mu\text{mol/L}$

Child 6 mo–2 yr: 40–100 $\mu\text{g/dL}$; SI units: 7.16–17.9 $\mu\text{mol/L}$

Total Iron Binding Capacity (TIBC)

250–460 $\mu\text{g/dL}$; SI units: 45–82 $\mu\text{mol/L}$

Serum Transferrin

200–430 mg/dL; SI units: 2–3.8 g/L

Transferrin Saturation

Male: 30–50%

Female: 20–35%

▶ Red-top tube.

■ Iron is critical to proliferation and maturation of red blood cells.

■ 65% of iron is found in hemoglobin. Most of the rest is stored as ferritin in the liver, bone marrow, and spleen.

■ Transferrin is the major transporting protein of iron.

■ Increased in excessive iron intake and decreased production of erythrocytes. Decreased in iron deficiency anemia, normochromic anemia associated with chronic diseases.

17-Ketosteroids (17-Ketogenic Steroids, 17-KGS, Corticosteroids)

Adult: Male: 8–25 mg/24 hr; SI units: 27–85 $\mu\text{mol}/24$ hr. Female: 5–15 mg/24 hr; SI units: 17–52 $\mu\text{mol}/24$ hr.

Child: <1–3 mg/24 hr (age dependent; the younger the child, the lower the normal range); SI units: 3–10 $\mu\text{mol}/24$ hr.

- ▶ 24-hr urine collection.
 - Aids in the diagnosis of adrenal cortex dysfunction.
 - Increased in Cushing's syndrome, stress, adrenocortical cancer, testicular and ovarian cancers, infection, pituitary hyperfunction.
 - Decreased in Addison's disease, nephrosis, pituitary hypofunction.

Lactate Dehydrogenase (LD, LDH), LDH Isoenzymes

LDH

Adult: 100–190 U/L but may differ significantly from lab to lab

LDH Isoenzymes

LDH-1: 17–27%

LDH-2: 27–37%

LDH-3: 18–25%

LDH-4: 3–8%

LDH-5: 0–5%

- ▶ Red-top tube.
 - Enzyme present in many body tissues.
 - Elevated levels occur in many disease states including MI, cancer, liver disease, muscle disease, and trauma.

Lactic Acid (Lactate)

Venous: 0.5–1.5 mEq/L or 8.1–15.3 mg/dL; SI units: 0.5–1.5 mmol/L

Arterial: 0.5–2 mEq/L or 11.3 mg/dL; SI units: 0.5–2 mmol/L

Critical Levels: (venous or arterial) >5 or >45 mg/dL; SI units: >5 mmol/L

- ▶ Green or gray-top tube. Send to lab on ice.
 - Sensitive indicator of tissue hypoxia.
 - Accumulation of excess lactic acid due to hypoxia coupled with decreased hepatic clearance leads to lactic acidosis.
 - Lactic acid levels are increased in hemorrhage, shock, sepsis, DKA, strenuous exercise, cirrhosis.

LeadAdult: 0–25 $\mu\text{g/dL}$; SI units: 0–1.2 mmol/LChild: 10–20 $\mu\text{g/dL}$; SI units: 0.48–0.966 mmol/L**Critical Levels: Adult: >40 $\mu\text{g/dL}$; Child: >30 $\mu\text{g/dL}$**

- ▶ Lavender-, navy-, or green-top tube (check with lab).
 - Excessive lead accumulation results in neurologic impairment; children are especially sensitive to lead poisoning.
 - Lethargy and coma are seen in adults with levels >60 mg/dL.

Legionnaire's Antibody Test

Negative

- ▶ Red-top tube.
 - Requires two specimens; first is taken at acute onset and second is taken at least 3 weeks later.
 - Considered diagnostic of Legionnaire's disease (acute respiratory infection with pneumonia) if the titer quadruples or if a single titer is >1:256.

Lipase

0–160 U/L; SI units: 0–160 U/L

- ▶ Red-top tube. Fasting sample.
 - Pancreatic enzyme elevated in acute pancreatitis.

Lipoproteins

See individual lipoproteins: Cholesterol, Triglycerides, and Phospholipids.

Liver Function Tests (LFTs)

See individual tests for reference ranges.

- ▶ Red-top tube.
 - A panel of tests used to evaluate liver function. Includes:
 - ◆ Alanine aminotransferase (ALT)
 - ◆ Alkaline phosphatase (ALP)
 - ◆ Aspartate aminotransferase (AST)
 - ◆ Bilirubin
 - ◆ Albumin
 - ◆ Total protein
 - Used in the evaluation of symptoms associated with liver disease (jaundice, nausea, vomiting and/or diarrhea; loss of appetite; ascites, hematemesis, melena; fatigue or loss of stamina; history of alcohol or drug abuse).

Low-density Lipoprotein (LDL)

See Cholesterol.

Luteinizing Hormone (LH)

Adult: *Male*: 7–24 IU/L; *Females*: 5–20 IU/L, with the midcycle peak approximately three times the baseline level. (Reference ranges vary with lab methodology.)

- ▶ Red- or lavender-top tube.
 - Ordered to evaluate fertility problems in men and women.

Lyme Disease Antibody

Negative/low titer (titer of 1:128 is borderline)

- ▶ Red-top tube.
 - A positive serology by ELISA is not definitive.
 - A Western blot can confirm the diagnosis of Lyme disease.

Lymphocyte Assay (CD4 marker, CD4/CD8 Ratio)

T cells: 60–80% or 600–2400 cells/ μ L

B cells: 4–16% or 50–250 cells/ μ L

CD4: 493–1191 μ L

CD8: 182–785 μ L; CD4/CD8 Ratio: >1

- ▶ Lavender-top tube.
 - Assessed in the diagnosis of AIDS, leukemias, lymphomas.
 - Used to guide drug therapy decisions in HIV infection and AIDS.
 - See White Blood Cells and Complete Blood Count.

Magnesium, Serum

1.6–2.2 mg/dL; SI units: 0.66–0.91 mmol/L

Critical Levels: <1 or >5 mg/dL

- ▶ Red-top tube.
 - Electrolyte critical to many metabolic processes including nerve impulse transmission, muscle relaxation, carbohydrate metabolism, and electrolyte balance.
 - Low levels may cause cardiac irritability, weakness, arrhythmias, seizures, and delirium.
 - Renal patients cannot excrete magnesium efficiently and thus are at risk for hypermagnesemia.

Methemoglobin

<1.5% of total hemoglobin. Levels >15% result in systemic symptoms; levels >70% are fatal.

- ▶ Lavender- or green-top tube. Deliver to lab on ice.
 - Methemoglobinemia occurs when iron in hemoglobin is oxidized to its ferric form. Methemoglobin binds so firmly with oxygen that less of it is available to tissues. Excess levels cause hypoxia.
 - Methemoglobinemia can be hereditary, but usually is acquired from drugs and chemicals, such as nitrites and aniline derivatives, which includes virtually all local anesthetics.
 - Excessive use of local anesthetics has caused fatal methemoglobinemia.

Microalbumin (MA, Urine Albumin, Albumin to Creatinine Ratio)

Microalbumin: 0–30 mg/day

Albumin to creatinine ratio: 0–30 μg albumin/mg creatinine; SI units: <2.5 mg albumin/mmol creatinine

- ▶ 24-hr or timed urine specimen.
 - This test measures minute amounts of albumin in the urine and is an early indicator of kidney damage, detecting kidney damage up to 5 years earlier than routine urine protein tests.
 - Is used to identify diabetics at risk for nephropathy so that appropriate intervention (ACE inhibitors to control hypertension and tight glycemic control).
 - Levels >300 mg/day (SI units: >300 mg/L) indicate irreversible nephropathy.
 - The timed test (4-hr or overnight urine sample) is less accurate than the 24-hr urine study. It uses a microalbumin to creatinine ratio to correct for variations in urine dilution.

Myoglobin, Serum

<90 $\mu\text{g/L}$; SI units: <90 $\mu\text{g/L}$

- ▶ Red-top tube.
 - Protein found in cardiac and skeletal muscle. Binds to oxygen and provides a reserve of oxygen during exercise.
 - Rises in 3 hrs after cardiac muscle damage and is therefore one of the first markers to rise after an MI.
 - Ordered in conjunction with troponin.

Myoglobin, Urine

Negative

Random urine sample.

- Myoglobin is released into the circulation, filtered by the glomeruli, and excreted by the kidneys following muscle injury.
- Elevations occur in skeletal muscle ischemia and trauma, MI, muscular dystrophy, rhabdomyolysis, and malignant hyperthermia.

5-Nucleotidase

<17U/L

- ▶ Red-top tube.
 - Indicator of liver damage secondary to biliary obstruction.

Osmolality, Serum278–298 mOsm/kg H₂O; SI units: 279–298 mmol/kg**Critical Levels: <265 or >320 mOsm/kg H₂O**

- ▶ Lavender- or green-top tube. Send to lab on ice.
 - Measures the concentration of particles in solution and therefore indicates hydration status.
 - Osmolality increases with dehydration and decreases with fluid overload.

Osmolality, Urine

24-hr urine: 300–900 mOsm/kg

Random sample: 50–1200 mOsmol/kg water

- ▶ Random, timed or 24-hr urine collection. Refrigerate specimen during collection.
 - Osmolality is a measure of the number of particles in solution.
 - Used to assess electrolyte and fluid balance, the kidneys' ability to concentrate urine, renal disease, diabetes insipidus (DI), and syndrome of inappropriate antidiuretic hormone secretion (SIADH).
 - Determination of both urine and serum osmolality aids in interpretation of results.

Parathyroid Hormone (Parathormone, PTH)

10–55 pg/mL; SI units: 10–65 ng/L

- ▶ Red-top tube. Fasting specimen. Calcium level should be drawn at the same time.
 - Secreted by the parathyroid gland; regulates calcium and phosphorus. Useful for diagnosing parathyroid problems.

Partial Thromboplastin Time (PTT)

20–35 sec

Critical Levels: >100 sec

- ▶ Blue-top tube.
 - Used to monitor therapeutic heparin, hirudin, or argatroban anticoagulation.
 - Therapeutic levels of anticoagulant are indicated by PTT of 1.5–2.5 times the control.

Parvovirus B19 Antibody

Negative

- ▶ Red-top tube.
 - Parvovirus B19 is responsible for fifth disease in children. Infection is self-limited and does not require treatment.
 - Parvovirus infection can cause fetal harm, infectious arthritis in adults, and severe anemia in immunocompromised patients.

Phenylketonuria Test (PKU Test, Guthrie Test)Guthrie blood test: ≤ 2 mg/dL; SI units: ≤ 121 $\mu\text{mol/L}$

PKU urine test: No green color.

- ▶ Heel stick to obtain a few drops of blood for filter paper or wet diaper for test stick or ferric oxide test.
 - PKU is a heritable disease characterized by an inability of the body to convert phenylalanine, present in protein foods, into tyrosine. Excess phenylalanine results in mental retardation.
 - All states mandate testing of newborns.
 - Children with PKU must be maintained on a low-phenylalanine diet for 6–to 8 years.

Phosphorus, Serum (Phosphate, PO_4)

Adult: 2.5–4.5 mEq/dL; SI units: 0.78–1.52 mmol/L

Child: 4.5–6.5 mg/dL; SI units: 1.45–2.1 mmol/L

Critical Levels: <1 mg/dL

- ▶ Red-top tube.
 - Phosphorus is critical to cellular metabolism, cell membrane integrity, and bone and teeth formation.
 - Increased in renal failure, hyperparathyroidism, diuretic abuse.
 - Decreased in hypoparathyroidism.

Plasminogen

80–120% of normal for plasma

▶ Blue-top tube.

- Plasminogen is the inactive precursor of plasmin. Plasmin participates in fibrinolysis.
- Used to evaluate hypercoagulable states such as thrombosis and DIC.

Platelet Antibodies (Antiplatelet Antibodies)

Negative

▶ One red-top tube and one lavender-top tube.

- Antibodies to platelets can result from an autoimmune response or a reaction to transfused blood products.
- The antibodies cause destruction of donor and native platelets.
- Positive platelet antibodies are found in AIDS, acute myeloid leukemia, immune complex diseases, drug-induced thrombocytopenia, posttransfusion purpura, and idiopathic thrombocytopenia purpura.

Platelets150,000–450,000/mm³; SI units: 150–450 × 10⁹/L**Critical Levels: <50,000 or >999,000/mm³**

▶ Lavender-top tube.

- Platelets are critical to hemostasis and blood clot formation.
- The number of platelets may be normal but their function impaired. Impaired platelet function is assessed by obtaining bleeding times.
- Increased platelets occur in many inflammatory disorders and myeloproliferative states as well as in acute or chronic blood loss, hemolytic anemias, after splenectomy, sudden exercise, cirrhosis, and iron deficiency.
- Thrombocytopenia (decreased platelets) occurs in aplastic anemia, megaloblastic and severe iron deficiency anemias, uremia, autoimmune thrombocytopenias, DIC, thrombotic thrombocytopenic purpura, following massive hemorrhage, in severe infection, and as a side effect of many different drugs including: abciximab, alcohol, allopurinol, carbamazepine, cimetidine, heparin, histamine blockers, most chemotherapeutic agents, nonsteroidal anti-inflammatories, procainamide, quinidine, quinine, ranitidine, rifampin.

Porphyrins, Urine

Total porphyrins	<i>Male:</i> 8–149 $\mu\text{g}/24\text{ hr}$; <i>Female:</i> 3–78 $\mu\text{g}/24\text{ hr}$
Uroporphyrin	<i>Male:</i> 4–46 $\mu\text{g}/24\text{ hr}$; <i>Female:</i> 3–22 $\mu\text{g}/24\text{ hr}$
Coproporphyrin	<i>Male:</i> <96 $\mu\text{g}/24\text{ hr}$; <i>Female:</i> <60 $\mu\text{g}/24\text{ hr}$
Porphobilinogen	0–2 $\text{mg}/24\text{ hr}$; SI units: 0.8–8.0 $\mu\text{mol}/\text{day}$

- ▶ 24-hr or random urine. Keep refrigerated. Protect from light.
 - Porphyrins are important in the synthesis of heme.
 - Porphyrins are genetic enzyme deficiencies.
 - Lead poisoning is also associated with excess urine porphyrins.

Potassium, Serum (K^+)

Adult: 3.5–5.0 mEq/L; SI units: 3.5–5.0 mmol/L

Child: 3.4–4.7 mEq/L; SI units: 3.4–4.7 mmol/L

Critical Levels: <2.5 or >6.5 mEq/L

- ▶ Red-top tube.
 - Very narrow normal range; small changes in potassium level can have profound effects on body functions.
 - Effects of potassium include transmission of nerve impulses; contraction of skeletal, smooth, and cardiac muscle; and maintenance of acid-base balance and osmolality.
 - Potassium levels may be decreased secondary to vomiting, diarrhea, diuretic use, insulin administration, burns, ascites, and other clinical conditions.
 - Increased levels occur with excessive IV administration, acute or chronic renal failure, potassium-sparing diuretics, infection, dehydration, transfusion of hemolyzed blood.

Prealbumin

20–40 mg/dL; SI units: 150–360 mg/L

- ▶ Red-top tube. Fasting sample.
 - Used to assess for malnutrition and to evaluate nutritional status of hospitalized patients, patients scheduled for surgery, and patients who are chronically ill.
 - Also used to monitor nutrition in patients receiving parenteral nutrition or who are on hemodialysis.

Progesterone

Adult: *Male*: < 0.3–1.2 ng/mL. *Female*: Follicular phase: 0.2–1.4 ng/mL; Luteal phase: 3.3–25.6 ng/mL; Midluteal phase: 4.4–28 ng/mL; 1st trimester: 11.2–90.0 ng/mL; 2nd trimester: 25.5–89.4 ng/mL; 3rd trimester: 48.4–422.5 ng/mL; Postmenopausal: 0–0.7 ng/mL

▶ Red-top tube.

- Progesterone prepares the uterus for implantation of a fertilized egg and may be used to confirm ovulation.
- Increased in molar pregnancy, adrenal hyperplasia.
- Decreased in placental deterioration, toxemia of pregnancy, fetal death, ovarian cancer, threatened spontaneous abortion.

Prostate-Specific Antigen (PSA)

0–4 ng/mL; SI units: <4 µg/L

▶ Red-top tube.

- PSA is a glycoprotein made by cells in the prostatic ducts.
- Test is used in the diagnosis and monitoring of prostate cancer.
- Levels >10 ng/mL are associated with prostate cancer.

Protein Electrophoresis

Protein Type	% of Total	As g/dL
Albumin	58–74%	3.5–5.5 g/dL
Alpha-1 globulin	2.0–3.5%	0.2–0.4 g/dL
Alpha-2 globulin	5.4–10.6%	0.5–0.9 g/dL
Beta globulin	7–14%	0.6–1.1 g/dL
Gamma globulin	8–18%	0.7–1.7 g/dL

▶ Red-top tube. May require random or 24-hr urine as well.

- Protein electrophoresis is a method for separating the proteins found in serum or urine. The proteins form a specific pattern in the electrical field. The pattern is then interpreted.
- Used to identify abnormal proteins and to detect monoclonal proteins (the abnormal production of one immunoglobulin).
- Ordered when multiple myeloma is suspected, when total protein or albumin levels are abnormal, or when urine protein levels are elevated.

Protein, Urine

30–140 mg/24 hr; SI units: 0.01–0.14 g/24 hr

- ▶ Random or 24-hr urine collection. Refrigerate during collection.
 - Urine normally contains only scant quantities of urine.
 - Used to assess renal function, preeclampsia, multiple myeloma.
 - See Bence Jones Protein.

Prothrombin Time (PT); International Normalized Ratio (INR)**Prothrombin time**

10–14 sec

Critical Levels: >30 sec

INR

2–3 for patients with PE, DVT, valvular heart disease; 2.5–3.5 for patients with prosthetic heart valve or recurrent systemic embolism.

- ▶ Blue-top tube.
 - The **PT** is the amount of time it takes blood to clot when mixed with a thromboplastin reagent. Normal values vary widely with different thromboplastin reagents. The **INR** uses a conversion factor that accounts for the differences in reagents. This allows the health care provider to evaluate and compare test results regardless of the reagents used by different laboratories.
 - Used primarily to evaluate warfarin therapy.
 - Therapeutic levels of warfarin are indicated by a PT one and a half to two times times the control.

Renin (Plasma Renin Activity)

Adult: *Normal sodium diet, upright:* 1–6 ng/mL/hr; SI units: 0.77–4.6 mmol/L/hr. *Sodium-restricted diet, upright:* 0.1–3.0 ng/mL/hr

- ▶ Lavender top-tube. Note position of patient (supine or upright) and normal or sodium-restricted diet.
 - Used in the diagnosis and treatment of hypertension.

Reticulocyte Count

Adult: 0.5–1.5% of all RBCs

Child: 0.5–2.0% of all RBCs

- ▶ Lavender top tube.
 - Reticulocytes are juvenile RBCs.
 - Used in to evaluate the etiology of anemia, erythropoietin therapy, and recovery from myelosuppression.

Rheumatoid Factor (RF)

<1:20 titer (agglutination method)

- ▶ Red-top tube.
 - Used in the diagnosis of rheumatoid arthritis.
 - RF is an antibody that attaches to immunoglobulin G (IgG).
 - Also elevated in collagen vascular diseases, infections, cancer, and MI.

Rotavirus Antigen

Negative

- ▶ Small amount of stool in a sterile container. Refrigerate immediately after collection.
 - Common cause of diarrhea in infants and young children.
 - Highly contagious; transmitted by the fecal-oral route.

SARS CoV, Serum

Negative coronavirus antibodies

- ▶ Gold-top tube.
 - Specimens should be collected when the diagnosis is first suspected and at later times if indicated.
 - An antibody response may be detected during the first week of illness, but a response is more likely by the end of the second week up to 28 or more days after onset of symptoms.

Sedimentation Rate (Erythrocyte Sedimentation Rate, ESR)

Adults (Westergren method): *Males under 50 yr: <15 mm/hr. Males: over 50 yr: <20 mm/hr. Females under 50 yr: <20 mm/hr; Females over 50 yr: <30 mm/hr.*

Children (Westergren method): *Newborn: 0 to 2 mm/hr; 6 mo-to 12 yr: 3-13 mm/hr.*

- ▶ Lavender-top tube.
 - Measures the rate at which red blood cells settle in saline or plasma at the bottom of a test tube. In certain disease states (inflammation, infection, cancer), erythrocytes stack together, increasing their weight and the rate at which they settle. Thus, increased sedimentation rate is an indicator of these diseases/conditions.
 - Used to monitor inflammatory or malignant disease, rheumatic fever, and heart attack.
 - Useful in monitoring tuberculosis, tissue necrosis, rheumatologic disorders, and other diseases.

Sickle Cell Screening Test

See Hemoglobin Electrophoresis.

Sodium, Serum

136–145 mEq/L; SI units: 136–145 mmol/L

Critical Levels: <120 or >160 mEq/L

- ▶ Red- or green-top tube.
 - Sodium is critical to body water distribution, maintenance of osmotic pressure, neuromuscular function, acid-base balance, and electrolyte balance.
 - Decreased in many clinical conditions including diarrhea, vomiting, nasogastric suction, SIADH, diuretics, and congestive heart failure.
 - Increased in excessive dietary or IV intake, Cushing's syndrome, diabetes insipidus, and excessive sweating.

Sodium, Urine

See Electrolytes, urine.

Sputum Culture and Sensitivity (Sputum C&S and Gram stain)

Normal flora

- ▶ Sputum specimen in sterile container.
 - To identify pathogenic organisms in the respiratory tract.
 - Discard specimens that are mostly saliva; obtain specimen from the bronchi after instructing the patient to cough effectively.
 - Some patients may require suctioning to obtain an appropriate sputum sample.

Stool Culture (Stool for C&S, Stool for Ova and Parasites [O&P])

Normal intestinal flora

- ▶ Small amount of stool specimen in a sterile container with a screw-top lid.
 - Evaluate cause of diarrhea.

Sweat Electrolytes**Sodium**

Normal: <70 mEq/L; Abnormal: >90 mEq/L; Equivocal: 70–90 mEq/L

Chloride

Normal: <50 mEq/L; Abnormal: >60 mEq/L; Equivocal: 50–60 mEq/L

- ▶ Collection of sweat on filter paper after iontophoresis (stimulation of sweating with pilocarpine).
 - Screening or diagnostic test for cystic fibrosis (CF).
 - Children with CF have increased sodium and chloride in their sweat.

T₃ Radioimmunoassay (Triiodothyronine)

75 to 220 ng/dL; SI units: 1.2–3.4 nmol/L

- ▶ Red-top tube.
 - Major hormone produced by the thyroid gland.
 - Used primarily to aid in the diagnosis of hyperthyroidism.

T₃ Resin Uptake (T₃RU, RT₃U, Resin T₃ Uptake)

24–37%

- ▶ Red-top tube.
 - Part of the thyroid function tests.
 - Measures the percentage of thyroid hormone bound to protein and therefore indicates the percentage of binding sites available.
 - T₃ uptake >37% indicates number of available binding sites is low, which occurs in hyperthyroidism.
 - T₃ uptake <37% indicates number of available binding sites is high, which occurs in hypothyroidism.

T₄ Total (Thyroxine Screen)

Adults: 4.5 to 11.2 µg/dL; SI units: 58–154 nmol/L

Infant (1 wk–4 mo): 9–16 µg/dL

Critical Levels: Adults: >18 µg/dL; Infant: <3.5 or >18.0 µg/dL

- ▶ Red-top tube.
 - Major hormone produced by the thyroid gland. Controls basal metabolic rate.
 - Used to screen for/diagnose hypothyroidism or hyperthyroidism.
 - Total T₄ measure all the T₄ both protein bound (96–99%) and free (1–4%).

T₄ Free (Free Thyroxine)

Adult: 0.8–2.8 ng/dL; SI units: 10–36 pmol/L

Neonate (to 4 days old): 2–6 ng/dL; SI units: 26–77 pmol/L

Child 2 wk–20 yr: 0.8–2.0 ng/dL

▶ Red-top tube.

- Total T₄ levels can be affected by protein levels in the blood and therefore give false results.
- Free or unbound T₄ is measured in patients with protein abnormalities to get a more accurate indicator of thyroid hormone.

Testosterone

Adult: *Male*: 300–1100 ng/dL; SI units: 9.71–38.14 nmol/L. *Female*: 15–70 ng/dL; SI units: 0.52–2.43 nmol/L

Child (10–11 yr old): *Male*: 5–50 ng/dL. SI units: 0.17–1.73 nmol/L.

Female: 5–25 ng/dL; SI units: 0.17–0.87 nmol/L

▶ Red- or green-top tube.

- Used to assess early or late puberty in boys and for evaluation of impotence and infertility in men.
- Used in the evaluation of excess hair growth, virilization (male body characteristics) and irregular menses in women.

Throat and Nares Culture

Normal flora

▶ Collect specimen in commercial culture swab.

- Identify pathogenic organisms from oropharynx and evaluate nares for staph colonization.
- To obtain throat culture, swab vigorously over both tonsils and the posterior pharynx avoiding the tongue and uvula.
- For nares, insert swab into nostril until it touches the posterior nares. Leave swab in place for 15 sec, rotate, and remove.
- *Neisseria gonorrhoeae* and *C. diphtheriae* require special media.

Thyroid Function Tests

See individual tests for reference ranges.

▶ Red-top tube.

- The thyroid gland produces three hormones: thyroxine (T₄), triiodothyronine (T₃) and calcitonin. T₃ and T₄ are collectively referred to as thyroid hormone.
- Thyroid hormone controls cellular metabolic activity and is critical to brain development and growth.

- Thyroid hormone secretion is controlled by TSH (thyroid-stimulating hormone) from the anterior pituitary gland.
- Laboratory thyroid function tests include TSH, T₃, T₄, Free Thyroxine, T₃ Resin Uptake, and Thyroid Antibodies.

Thyroid Antibodies (Antithyroglobulin Antibody and Antimicrosomal Antibody)

Negative

- ▶ Red-top tube.
 - Confirm the cause of thyroid dysfunction.
 - Microsomal antibodies are produced in response to microsomes released from damaged thyroid cells.

Thyroid-stimulating Hormone (TSH)

0.4–4.2 μ U/mL: SI units: 0.4–4.2 mU/L

Neonates: <20 μ U/mL: SI units: <20 mU/L

- ▶ Red-top tube.
 - Best screening test for thyroid function.
 - Increased levels indicate hypothyroidism; decreased levels indicate hyperthyroidism.
 - Also used to monitor thyroid hormone replacement therapy.

TORCH Screen (Toxoplasmosis, Rubella, Cytomegalovirus, Herpes Viruses)

Negative

- ▶ Red-top tube.
 - Detect maternal and infant infection.
 - High levels of immunoglobulin IgM against any of the microorganisms indicates congenital infection.

Transferrin

Adult: 220–430 mg/dL: SI units: 2.2–4.3 g/L

Newborn: 125–175 mg/dL: SI units: 1.25–2.75 g/L

- ▶ Red-top tube. Fasting sample.
 - Transferrin transports circulating iron to bone marrow for hemoglobin synthesis or to the liver, spleen, and bone marrow for storage.
 - Increased in iron deficiency anemia.
 - Decreased in liver damage, malnutrition, renal disease, and infection.

Triglycerides

Adult: <150 mg/dL; SI units: <1.7 mmol/L

Child (over 10 yr): *Male*: 32–148 mg/dL; SI units: 0.36–1.67 mmol/L. *Female*: 37–124 mg/dL; SI units: 0.42–1.4 mmol/L

- ▶ Red-top tube. Fasting sample.
 - Triglycerides are fats and are assessed as part of a lipid profile.
 - Levels >1000 mg/dL are associated with pancreatitis.

Troponins (Tnl, TnT)

Cardiac troponin T: <0.2 ng/mL

Cardiac troponin I: <0.03 ng/mL

- ▶ Yellow-top tube.
 - Proteins that help regulate cardiac contractility.
 - Sensitive biomarker of cardiac muscle injury.
 - Troponins become elevated earlier and remain elevated longer than CPK-MB, which allows for earlier diagnosis and initiation of thrombolytic therapy.

Tuberculosis Culture (TB Culture, AFB Smear)

No acid-fast bacilli observed on smear or isolated in culture.

- ▶ Sealed or screw-topped container for all specimen types (sputum, urine, other body tissue or fluid). Urine and sputum cultures are collected serially (usually for 3 days). Sputum specimen should be obtained in the early morning; induced sputum may be required if specimen is inadequate. Send to lab immediately.
 - Tuberculosis is diagnosed by culturing *Mycobacterium tuberculosis* from a specimen.
 - AFB smear (smear for acid-fast bacilli) is performed in addition to the culture. A second specimen may be required for the AFB smear if the volume of specimen is inadequate. AFB is used to monitor therapy effectiveness.
 - Antibiotic sensitivity may be performed as well.

Tumor Necrosis Factor- α (TNF- α , Cachectin)

<8.1 pg/mL

- ▶ Red-top tube
 - TNF- α is cytokine (an immune system protein) involved in systemic inflammatory processes.
 - Inhibition of TNF- α is part of the treatment strategy for autoimmune diseases such as rheumatoid arthritis.
 - Elevated in sepsis, autoimmune diseases, infectious diseases, and transplant rejection.

Uric Acid, Serum

Adult: *Male*: 4.0–8.5 mg/dL; SI units: 0.24–0.51 mmol/L. *Female*: 2.8–7.3 mg/dL; SI units: 0.16–0.43 mmol/L

Child: 2.5–5.5 mg/dL; SI units: 0.12–0.32 mmol/L

Critical Levels: >12 mg/dL

- ▶ Red-top tube.
 - Uric acid is the end product of purine metabolism.
 - Useful to assess for gout and to monitor patients with renal failure or to monitor if uric acid levels are too high after chemotherapy or radiation.

Uric Acid, Urine

Low purine diet: 250–500 mg/day; Unrestricted diet: 250–750 mg/day

- ▶ 24-hr urine. Refrigerate during collection.
 - Assess for elevated levels of urine uric acid in patients with renal calculus formation or identify patients at risk for stone formation.
 - Uric acid kidney stones occur in gout or secondary to malignant diseases, ulcerative colitis, Crohn's disease, and surgical jejunioileal bypass.

Urinalysis (UA)

Characteristic	Normal Finding
Appearance and color	Clear; yellow, straw
pH	4.6–8.0
Protein	2–8 mg/dL
Specific gravity	1.005–1.030
Leukocyte esterase	Negative
Nitrite	Negative
Glucose	Negative
Ketones	Negative
White blood cells	3–4
White blood cell casts	Negative
Red blood cells	1–2
Red blood cell casts	Negative
Crystals	Few/Negative

▶ Random urine sample.

- Urinalysis provides information about the renal/urinary system.
- **Protein** content in urine is indicative of decreased renal function.
- **Specific gravity** measures the concentration of particles in the urine and is an indicator of the kidney's ability to concentrate urine. It also reflects overall hydration status. Low specific gravity indicates that the urine is dilute; high specific gravity means that the urine is concentrated (volume depletion).
- **Leukocyte esterase, nitrite,** and white blood cells in the urine are an indication of urinary tract infection.
- **Red blood cells** indicate of damage to the renal tubules.
- **Crystals** indicate the presence of renal stones.
- **Casts** are clumps of cells formed in the tubules. **Hyaline casts** indicate protein in the urine. **WBC and RBC casts** are generally indicative of upper urinary tract infection. RBC casts are also present in other serious kidney disorders. **Renal tubular epithelial cell casts** reflect damage to the tubules and are found in renal tubular necrosis, viral disease, and transplant rejection.

Urine Culture and Sensitivity (Urine C&S)

Negative or No Growth

- ▶ Clean catch mid-stream urine sample, or aseptic aspiration of urine from a closed urinary drainage system, in a sterile container.
 - Test for pathogenic bacteria in patients with suspected UTI or abnormal urinalysis results (positive leukocyte esterase, increased number of WBC in urine, bacteria in urine).
 - Test includes determining to which antibiotics the bacteria are sensitive.
 - Bacterial counts $>100,000/\text{mL}$ of a single organism indicate a UTI.

Urobilinogen0–4 mg/24hr; SI units: 0.09–4.23 $\mu\text{mol}/24\text{ hr}$

- ▶ 24-hour urine collection.
 - An increase in urobilinogen indicates hepatocellular dysfunction or an increased bilirubin production due to hemolysis.
 - Absence of urobilinogen indicates complete biliary obstruction.

VDRL (Venereal Diagnosis Research Laboratory, Rapid Plasma Reagin, RPR)

Negative

- ▶ Red-top tube.
 - Used to diagnose syphilis infection.
 - Blood test detects antibodies to *Treponema pallidum*; therefore indicates current or past infection.
 - Lumbar puncture and CSF analysis are necessary to detect neurosyphilis.

Viral Culture

Negative

- ▶ Lavender-top tube for blood; other specimens (cerebrospinal fluid; dermal, ocular, genital, mucosal, oral, or rectal lesions; respiratory washings; stool, tissue, urine, or biopsy specimens) sent in sterile container, viral culturette swab, or lab-provided medium). Transport specimens immediately or refrigerate.
 - Assess body tissue for adenovirus, cytomegalovirus, enteroviruses, herpes simplex virus, influenza, mumps, parainfluenza, RSV, etc.

Viral Load (Plasma Viral Load, PVL)

Results range from No Detectable Virus and Low Levels (200–500 copies/mL) to High Levels (>10,000 copies/mL)

- ▶ Lavender-top tube.
 - Indicates the amount of HIV-RNA present in the blood.
 - Used to monitor the status of HIV disease and inform therapy changes.
 - Tests are performed serially with treatment changes to monitor treatment response.

Vitamin B₁₂

160–900 pg/mL; SI units: 118–690 pmol/L

- ▶ Red-top tube.
 - B₁₂ is essential to the proper formation and function of RBCs.
 - B₁₂ deficiency can result from insufficient intake of foods containing B₁₂; malabsorption from celiac disease, reduced stomach acid, lack of intrinsic factor (pernicious anemia) or surgical resection of the stomach or small intestine; liver and kidney diseases, alcoholism, and certain medications.
 - Ordered to establish cause of macrocytic anemia.

West Nile Virus

Negative

- ▶ Red-top tube.
 - Involves testing for IgM and IgG West Nile virus (WNV) antibodies or testing for WNV genetic material.
 - Indicates current or recent infection.
 - May be assessed repeatedly to determine if antibody levels are stable, rising, or falling.

White Blood Cell Count and Differential

	Conventional Absolute (Percentage)	SI Units
Total WBC	4,300–10,800/mm ³	4.3–10.8 × 10 ⁹ /L
Total Neutrophils	2500–8000 (55–70%)	2.5–80 × 10 ⁹ /L
◆ Neutrophils, bands	0–700 (0–5%)	0.03–0.08 × 10 ⁹ /L
◆ Neutrophils, segmented	1800–7000 (54–65%)	0.54–0.65 × 10 ⁹ /L
Lymphocytes	1000–4000 (25–40%)	0.25–0.40 × 10 ⁹ /L
◆ T cells	600–2400 cells/μL	600–2400 cells/μL
◆ B cells	50–250 cell/μL	50–250 cell/μL
Monocytes	100–700 (2–8%)	0.02–0.08 × 10 ⁹ /L
Eosinophils	50–500 (1–4%)	0.01–0.04 × 10 ⁹ /L
Basophils	25–100 (0–1%)	0–0.01 × 10 ⁹ /L

▶ Lavender-top tube.

- White blood cells are crucial to defending the body from foreign organisms, tissues, and other substances.
- An elevated white blood cell count (leukocytosis) usually represents an increase in one of the types of WBCs rather than an increase in all the types of cells.
- An **increased lymphocyte count** is seen in infectious mononucleosis, viral hepatitis, cytomegalovirus infection, other viral infections, pertussis, toxoplasmosis, brucellosis, TB, syphilis, lymphocytic leukemias, chronic bacterial infection, and multiple myeloma.
 - ◆ An **increased neutrophil count** may indicate acute infection, eclampsia, gout, myelocytic leukemia, rheumatoid arthritis, rheumatic fever, acute stress, thyroiditis, trauma.
 - “**Left shift**” occurs when there is more than 10–12% bands or when the sum of bands plus segmented neutrophils is >80%.
 - The left shift represents an increase in the percentage of immature **band neutrophils** to mature segmented neutrophils and occurs in bacterial infection and toxemia but can also occur in acute stress situations.

- T cells, specifically **CD-4 T cells** are monitored in patients who are HIV positive.
- ◆ An **increased eosinophil count** occurs in allergic disorders, parasitic infection, and Hodgkin's disease.
- ◆ An **increased monocyte count** may indicate chronic inflammatory disease, parasitic infection, tuberculosis, and viral infection.
- Decreased white blood cell count is called leukopenia.
 - ◆ **Decreased lymphocytes** is the hallmark of AIDS. It also occurs in acute infections, Hodgkin's disease, leukemia, sepsis, systemic lupus, renal failure, and radiation sickness.
 - ◆ **Decreased neutrophils** may occur in aplastic anemia, influenza, chemotherapy, overwhelming bacterial infection, and secondary to medications including:
 - Analgesics and anti-inflammatories
 - Antibiotics
 - Anticonvulsants
 - Antimetabolites
 - Antineoplastics
 - Antithyroid drugs
 - Arsenicals
 - Barbiturates
 - Cardiovascular drugs
 - Diuretics

Wound Culture

No growth, routine or normal skin flora, routine or normal flora for body area cultured.

- ▶ Collect exudate or tissue sample in a sterile specimen cup (with screw-top lid) or swab in culture tube. Aspirated exudate may be sent to lab in syringe with needle removed. Source of specimen must be identified.
 - To identify pathogenic organisms in wounds.
 - Common organisms cultured from wounds include *Escherichia coli*, *Proteus*, *Klebsiella*, *Pseudomonas*, *Enterobacter*, enterococci, other streptococci, *Bacteroides*, *Prevotella*, *Clostridium*, *Staphylococcus aureus*, and coagulase-negative *Staphylococcus*.

Xylose Tolerance test

	2 hr (plasma)	5 hr (urine)
Adult	>32–58 mg/dL	>4 g/5 hr (16–32%)

- ▶ Gray-top tube; fasting sample and sample 2 hr after ingestion of xylose. Plastic urine container for urine sample.
 - After ingestion, xylose is absorbed by the small bowel and 30–40% excreted in the urine. Intestinal malabsorption is indicated by low blood levels and decreased urine excretion.
 - Decreased levels seen in celiac diseases, tropical sprue, Crohn's disease, immunoglobulin deficiency, pellagra, radiation enteritis, surgical bowel resection, vomiting, delayed gastric emptying, thyroid disease, ascites, and increased intestinal motility.

Zinc







60–130 mg/dL; SI units: 9–20 mmol/L

- ▶ Royal blue-top tube.
 - Zinc contributes to RNA and DNA synthesis and is essential to tissue repair.
 - Used to evaluate suspected nutritional deficiency, especially for burn patients and patients receiving enteral or parental nutrition.
 - Useful in evaluating patients with delayed wound healing or growth retardation.

General Description and Process

- X-rays are used to evaluate the structure of bones and soft tissues.
- X-rays are similar to visible light, but have a shorter wavelength.
- The patient is placed between x-ray machine and specially treated film.
- Gamma rays created in the x-ray machine pass through the patient's body.
- Different internal structures absorb the x-rays in varying amounts, which results in shadows of varying shades of gray being cast on the film.
- The amount of x-rays absorbed and therefore the image on the film varies according to the composition and density of tissues. The greater the density, the more radiopaque the image; the lesser the density, the more radiolucent the image.
 - ◆ *Dense structures such as bone absorb most of the x-rays and appear white on film.*
 - ◆ *Air-filled structures do not absorb x-rays and appear black.*
 - ◆ *Fat, muscle, and fluids appear as shades of gray.*
- Images may be enhanced with contrast medium.

Radiodensity

	Air appears black and is the most radiolucent
	Fat appears very dark gray
	Water appears medium gray
	Bone appears light medium gray
	Contrast appears very light gray
	Heavy metals (foreign objects, joint prostheses) appear white and are the most radiopaque

Terms

Attenuation: process by which radiation loses power as it travels through body tissues and interacts with them. Attenuation creates the contrast observed in x-ray images.

Contrast: the difference in brightness between the light and dark areas of a picture or image.

Contrast-mediated x-rays: radiologic studies of soft tissues in which contrast media have been used to enhance the structural details visible on film.

Contrast medium: substance that alters the contrast by increasing or decreasing attenuation. Barium sulfate and iodine are the most commonly used contrast media.

Fluoroscopy: x-rays are passed through the patient to a viewing screen so that movement of structures can be observed.

Plain x-rays: radiologic studies performed without contrast media or other supplemental technique. Used for bones or air-filled structures (e.g., chest, abdomen).

Tomography: radiographic imaging technique in which the x-ray source and the film are moved in opposite directions. This results in a two-dimensional image of a specific plane. (See CT scans.)

Xeroradiography: technique that uses a photoelectrical process similar to photocopying. Useful for soft tissue imaging such as mammography.

Basic Positions for X-rays

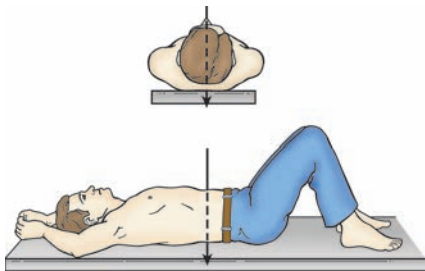
AP (anterior-posterior): X-ray passes through patient from front to back.

PA (posterior-anterior): X-ray passes through patient from back to front.

Lateral: Patient is positioned on either side and so that the x-ray passes from one side of body through the other.

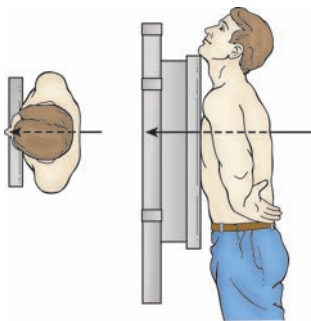
Oblique: X-ray is angled between PA and lateral positions. (see Figures)

Anterior-Posterior Position (AP)



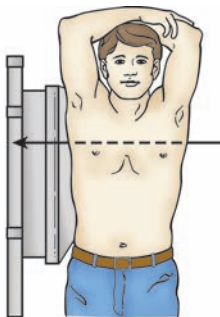
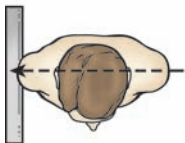
Anterior-posterior position.

Posterior-Anterior Position

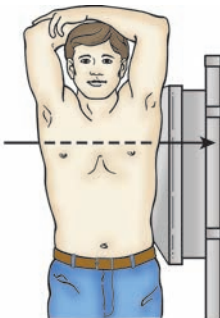
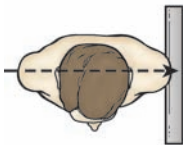


Posterior-anterior position.

Lateral Positions

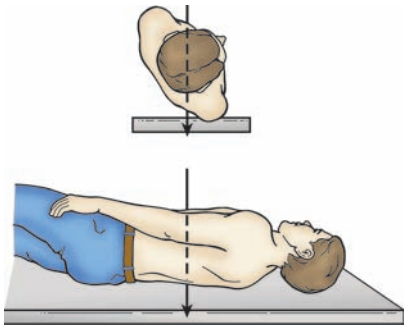


Right lateral position.

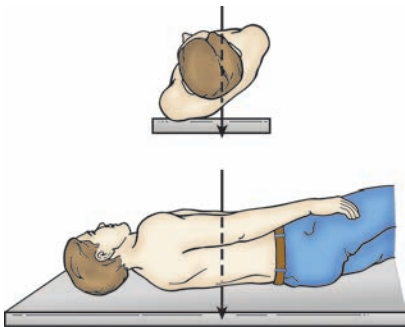


Left lateral position.

Posterior Oblique Positions

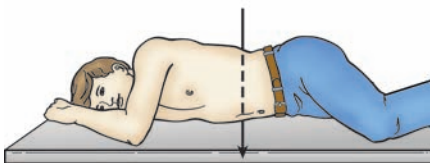
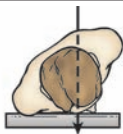


Right posterior oblique position.

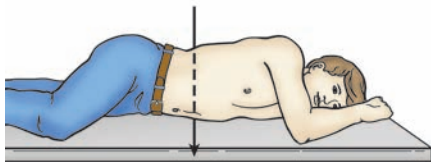
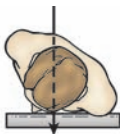


Left posterior oblique position.

Anterior Oblique Positions



Right anterior oblique position.



Left anterior oblique position.

PLAIN X-RAYS**General Patient Preparation for Plain X-rays**

- Determine if the patient is pregnant or may be pregnant. X-ray is contraindicated unless benefit to mother outweighs risk to fetus.
- The reproductive organs are shielded during x-ray unless abdominal films are needed on a female.
- If scheduled for abdominal films, determine if the patient has had a barium contrast study or taken medications containing bismuth in the previous 4 days. (Films will need to be postponed until all contrast is excreted.)
- Tell the patient that he or she will have to stay very still while films are being taken (approximately 1 sec for each view).
- Remove metal objects and jewelry. If jewelry has psychological or spiritual significance for the patient, it can usually be held by the patient or moved to a part the body not under examination.

Abdominal X-ray

Plain film of the abdomen; also called abdominal flat plate or KUB for kidneys, ureter, and bladder.

PURPOSE

- Assess cause of abdominal pain.
- Evaluate liver or kidney size, shape, and position.

PROCEDURE

Patient lies supine on the x-ray table. Males will have the testicles shielded. One AP (anterior-posterior) image is taken unless abdominal x-ray is part of an Obstruction Series.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Tell patient that he or she will have to take a deep breath and hold it or exhale and not breathe for 2 or 3 sec while pictures are taken.
- Tell patient not to expect discomfort during test.

POSTTEST CARE

- No special posttest care required.

Bone Densitometry (Bone Mineral Density, BMD, DEXA Scan)

Uses an enhanced type of x-ray technology called dual-energy x-ray absorptiometry to measure bone density. A portable DEXA device can be used to measure bone density in the wrist, heel, or fingers. The larger device, available in hospitals, usually assesses density of the lower spine or hip. Although DEXA is the most widely used scan, other methods for assessing bone density, including ultrasound and computed tomography, are also available.

PURPOSE

- Identify risk for osteoporosis.
- Monitor rate of bone loss in patients with osteoporosis.

PROCEDURE

The patient lies on a padded table. The x-ray generator is below the table and the detector is above. A narrow beam of low-dose x-rays from below the padded table passes through the bone while an arm above the table scans the body, detecting the x-ray beam. Software interprets the data, providing both an image of the bone and an analysis the density of the bone matrix.

Test results are reported in terms of standard deviations from the norm. A score of greater than -1 is considered normal. A score between -1 and -2.5 is classified as **osteopenia**, the first stage of bone loss. A score of less than -2.5 indicates osteoporosis.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- The patient will have to remove jewelry if it is in the x-ray field. If jewelry has psychologic or spiritual significance, the patient may hold the jewelry during the procedure.
- Although x-rays are not painful, some patients may experience discomfort related to repositioning.
- The patient will have to stay still during the test.

POSTTEST CARE

- No special posttest care required.

Bone X-rays (Clavicle, Scapula, Foot, Hand, Toe, Finger, Mandible)

Plain films of bones or joints including the clavicle, scapula, foot, hand, finger, toe, and mandible. See Long Bone X-rays.

PURPOSE

- Assess for fracture, tumor, infection, structural abnormalities, degenerative diseases.
- Evaluate pain, loss of function, deformity.

PROCEDURE

The patient may stand or sit, or lie on the x-ray table depending upon the anatomic part being studied.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- The patient will have to remove jewelry if it is in the x-ray field. If jewelry has psychologic or spiritual significance, the patient may hold the jewelry during the procedure.
- Although x-rays are not painful, some patients may experience discomfort related to repositioning.

POSTTEST CARE

- No special posttest care required.



Plain film of hand showing metacarpal fracture

Chest X-ray

Plain film of the chest. Different possible views include:

- ◆ PA (posterior-anterior): diminishes image of heart making other structures clearer.
- ◆ AP (anterior-posterior): enhances cardiac image.
- ◆ Lateral: heart is less magnified.
- ◆ Oblique: aids in evaluation of lung masses and infiltrates.
- ◆ Lateral decubitus (cross-table lateral): used when fluid in chest cavity is suspected.

PURPOSE

- Assess lung fields, cardiac border, large arteries, clavicle, ribs, diaphragm, and mediastinum.
- Diagnose pulmonary or cardiac disorders including heart failure, COPD, pneumonia, TB, and neoplastic disease.
- Evaluate placement of feeding tubes, chest tubes, central venous catheters, pacemaker wires, endotracheal tubes, etc.

PROCEDURE

Patient stands or is placed in appropriate position. Reproductive organs and thyroid gland may be shielded. Images are taken, frequently PA and lateral.

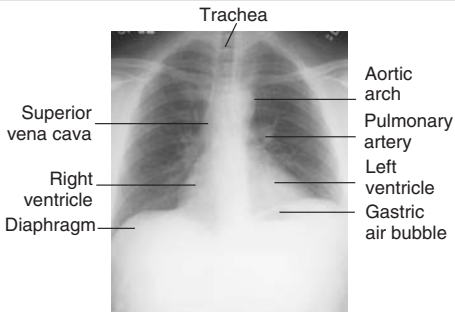
PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Tell patient that he or she will have to take a deep breath and hold it for 2 or 3 sec while pictures are taken.
- Tell patient that metal necklaces will need to be removed. If jewelry has psychologic or spiritual significance, the patient may hold the jewelry during the procedure.
- Tell patient not to expect discomfort during test.

POSTTEST CARE

No special posttest care required.

Chest X-ray with Anatomic Landmarks



Chest x-ray showing anatomic structures.

Abnormal Chest X-ray



Abnormal densities of lung cancer.

Joint X-rays

Plain films of a joint or joints (hip, knee, shoulder, elbow, ankle, wrist, joints in the feet and hands, etc).

PURPOSE

- Assess for fracture, infection, cysts, tumor, degenerative diseases.

PROCEDURE

The patient lies on the x-ray table while various views of the joint are taken.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- The patient will have to remove jewelry if in the x-ray field.
- Although the x-ray is not painful, some patients may experience discomfort when painful joints are manipulated and repositioned for x-ray.

POSTTEST CARE

- No special posttest care required.

Long Bone X-rays

Plain film of a long bone such as the femur, tibia/fibula, humerus, or radius/ulna.

PURPOSE

- Evaluate bone pain or assess for fracture, tumor, infection, joint or bone deformity.

PROCEDURE

Patient may lie on the x-ray table or sit depending on extremity to be filmed. Several views may be taken.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Although the x-ray is not painful, some patients may experience discomfort from having an injured or painful extremity positioned for x-ray.

POSTTEST CARE

- No special posttest care required.

Mammography

X-ray (xeroradiography) of the breasts.

PURPOSE

- Detect tumors, cysts, and other breast disorders.
- Differentiate between malignant and benign lesions.

PROCEDURE

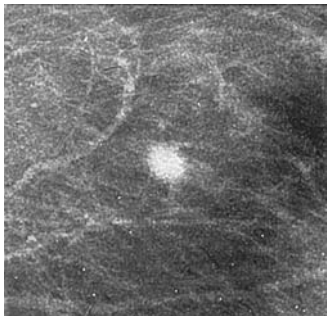
The patient either sits or stands in front of the x-ray machine. One breast at a time is rested on a flat surface that contains the x-ray plate. A compressor firmly presses against the breast to flatten the tissue. X-ray films are taken from several angles while the patient holds her breath.

PRETEST PREPATION

- Remove metal objects and jewelry from around the neck or chest. If jewelry has psychologic or spiritual significance for the patient, it can be held by the patient or moved to a part of the body not under examination.
- Tell the patient not to wear talcum powder or deodorant the day of test.
- Explain that some patients experience brief discomfort from breast compression and that the test takes 15 min.

POSTTEST CARE

- No special posttest care is required.



Mammogram showing breast cancer

Obstruction Series

Plain film of the abdomen plus abdominal films in other positions.

PURPOSE

- Assess for bowel obstruction, paralytic ileus, bowel perforation.

PROCEDURE

Patient stands erect and lies supine while abdominal films are taken. Other views may include cross-lateral (lateral decubitus) and lower chest.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Tell patient that he or she will have to take a deep breath and hold it or exhale and not breathe for 2 or 3 sec while pictures are taken.
- Tell patient not to expect discomfort during test.

POSTTEST CARE

- No special posttest care required.

Orbital X-rays

Plain film of the orbits of the eyes.

PURPOSE

- Assess for fracture, foreign body, tumor, congenital abnormality.

PROCEDURE

Patient may lie on the table or sit in a chair. Several views may be taken with the head immobilized by sand bags or foam pads.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- The patient will have to remove jewelry from the head and neck and dentures.
- Although the x-ray is not painful, some patients may experience discomfort if recent history of head or neck trauma.

POSTTEST CARE

- No special posttest care required.

Paranasal Sinuses X-rays

Plain films of facial sinuses.

PURPOSE

- Assess for fracture, infection, cysts, tumor, foreign body.

PROCEDURE

Patient sits in an x-ray chair. The patient's head is placed in a padded brace for proper immobilization. Several views may be taken.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- The patient will have to remove jewelry from the head and neck and dentures.
- Although the x-ray is not painful, some patients may experience discomfort if recent history of head or neck trauma.

POSTTEST CARE

No special posttest care required.

Skull X-rays

Plain film of cranial vault, facial bones.

PURPOSE

- Assess for fracture, infection, tumor.

PROCEDURE

Patient may lie on the x-ray table or sit in a chair. Several views are taken, which require the patient to assume different positions and may require varying degrees of neck flexion. The head will be immobilized with sand bags or foam pads.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- The patient will have to remove jewelry from the head and neck, and dentures.
- Although the x-ray is not painful, some patients may experience discomfort if recent history of head or neck trauma.

POSTTEST CARE

- No special posttest care required.

Spinal X-rays

Plain films of the cervical, thoracic, lumbar, sacral or coccygeal spine.

PURPOSE

- Assess back and neck pain, assess for fracture, tumor, spinal alignment abnormalities, degenerative diseases.

PROCEDURE

The patient lies on the x-ray table while various views of the spine are taken.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- The patient will have to remove jewelry if it is in the x-ray field. If jewelry has psychological or spiritual significance, the patient may hold the jewelry during the procedure.
- Although the x-ray is not painful, some patients may experience discomfort related to repositioning for x-ray.

POSTTEST CARE

- No special posttest care required.



Degenerative disc disease of the cervical spine. Decreased disc space at C5-6 with osteophyte formation anteriorly (white arrow) and posteriorly (black arrow).

CONTRAST-MEDIATED X-RAYS

Contrast Agents

Contrast agents enhance visualization of structures that do not show up well on x-ray alone. They do this by blocking the passage of x-rays, which causes the structures to appear white on the film. The most commonly used contrast media contain **barium** (for gastrointestinal studies) or **iodine** (for other studies). Contrast agents containing iodine are referred to as iodinated contrast media (ICM) and are capable of causing severe adverse reactions. Iodinated contrast media are categorized as **ionic** or **nonionic** and **high osmolality** or **low osmolality**. **Ionic** contrast media dissolve into charged particles in the bloodstream. They are associated with a higher incidence of adverse reactions because the charged particles can disrupt cardiac and neural electrical activity. **Nonionic** contrast agents do not dissolve into charged particles and are considered safer. **Osmolality** is the concentration of particles or molecules of solids dissolved or suspended in solvent or liquid. A contrast with a **high osmolality** has a higher number of particles in solution and is associated with adverse reactions (see section on Osmolality below).

Mild adverse reactions (see Table) are not uncommon; severe reactions are rare but potentially life-threatening. Reactions are more common when contrast is administered IV.

🚫 **Because of the risk of adverse reaction, informed consent is required when an iodinated contrast medium is used.**

Osmolality and Adverse Reactions

Although adverse reactions often look like an allergic response, the effects are related to the **osmolality** of the injected substance rather than an allergy to iodine.

- ◆ Introduction of highly osmolar fluids into the bloodstream causes fluid shifts resulting in fluid overload and compensatory blood vessel dilation, which causes cardiovascular effects (see Table).

- ◆ Vasoconstricting substances are released into the system as a result of the arterial dilation. This can result in diminished blood supply to the kidneys and kidney damage.
- ◆ Homeostasis will be disrupted less if the contrast agent has an osmolality similar to that of blood plasma, which is 300 osmol/kg.
- ◆ Low-osmolality contrast has an average osmolality of 750 osmol/kg or less, whereas high-osmolality contrast has an osmolality of 1000–2400 osmol/kg.
- ◆ Anaphylactoid reactions also occur, although the mechanism is not well understood; true iodine allergies are very rare.

Contrast Agents

High-Osmolality Agents (Higher risk of reaction)

- ◆ Diatrizoate sodium (Hypaque)
- ◆ Iodamide meglumine (Renovue)
- ◆ Iothalamate meglumine (Conray)
- ◆ Oral cholecystographic agents (Telepaque)

Low-Osmolality Agents (Lower risk of reaction)

- ◆ ioxaglate meglumine (Hexabrix)
- ◆ gadodiamide (Omniscan)
- ◆ gadoteoridol (ProHance)
- ◆ iodixanol (Visipaque)
- ◆ iopamidol (Isovue)
- ◆ ipromide (Ultravist)
- ◆ ioversol (Optiray)

Risk Factors for Adverse Reactions to Contrast

The following conditions are associated with an increased risk of adverse reaction to ICM:

- Previous reaction
- Asthma (severe reactions are five to nine times more common)
- Allergy
- Diabetes (for nephropathic reactions)
- Renal failure (for nephropathic reactions)
- Severe cardiac disease
- Dehydration (for nephropathic reactions)
- Extremes of age (newborn or >65 years old)
- Seizure disorder
- Liver disease
- Multiple myeloma (if renal involvement)

Contrast Reaction Prevention Strategies

- Use low-osmolality, nonionic agents.
- Avoid concurrent administration of nephrotoxic drugs.
- Discontinue metformin (Glucophage) the day of the test and do not administer for 48 hr. Resume only after renal function has normalized.
- Use an anaphylactoid reaction prevention protocol (indicated for patients with prior contrast reaction):
 - ◆ Corticosteroid protocol: either methylprednisolone 32 mg at 12 and 2 hr before contrast or prednisone 50 mg at 13, 7, and 1 hr before contrast.
 - ◆ Diphenhydramine 50 mg 1 hr before contrast.
- Use an acute renal failure prevention protocol:
 - ◆ Avoid concurrent nephrotoxic drugs.
 - ◆ Use low-osmolality contrast material.
 - ◆ Allow 2–5 days between IV contrast procedures.
- Hydrate before and after procedure:
 - ◆ $1/2$ NS or NS, 100 mL/hr 4 hr precontrast and 24 hr postcontrast (adjust for congestive heart failure) OR
 - ◆ Oral (noncaffeinated) fluid 500 mL before contrast and 2500 mL over 24 hr postcontrast.
- Adjust IV contrast dose:
 - ◆ Contrast dose: $(5 \text{ mL/kg})/(\text{serum creatinine})$.
 - ◆ Maximum total dose: 300 mL.

METFORMIN (GLUCOPHAGE) AND IODINATED CONTRAST MEDIA

In patients with renal failure, metformin, which is excreted by the kidneys, may build up to dangerous levels causing potentially fatal lactic acidosis. Since administration of iodinated contrast media (ICM) can cause acute renal failure, particularly in those at risk for renal compromise (diabetics), metformin should be temporarily discontinued.

👉 **Metformin should be discontinued the day of testing and withheld for 48 hr after testing. It should be restarted only after renal function has returned to normal.**

Reactions to Iodinated Contrast Media (ICM)

	Signs and Symptoms	Treatment
Anaphylactoid Reaction	Mild symptoms: scattered urticaria, pruritus; rhinorrhea; nausea, vomiting; diaphoresis; coughing; and dizziness.	<ul style="list-style-type: none"> ✓ Observe for progression to more severe reaction, which requires immediate intervention. ✓ Administer antihistamines for itching or prochlorperazine for nausea and vomiting if necessary.
	Moderate symptoms: persistent vomiting; diffuse urticaria; headache; facial and or laryngeal edema; mild bronchospasm; dyspnea; palpitations, tachycardia, bradycardia; hypertension; abdominal cramps.	<ul style="list-style-type: none"> ✓ Provide O₂ at 10–12 L/min via face mask. ✓ Monitor vital signs every 5 min. ✓ Administer antihistamines, initiate IV access with NS or D5W. ✓ Possible administration of epinephrine, steroids, and bronchodilators.
	Severe symptoms: life-threatening arrhythmias (V-tach); hypotension; overt bronchospasm; laryngeal edema; pulmonary edema; seizures; syncope; cardiopulmonary arrest	<ul style="list-style-type: none"> ✓ Administer epinephrine 0.3–0.5 mg subQ every 10–20 min and methylprednisolone 50 mg IV. ✓ Give beta agonist inhaler (e.g., albuterol) for bronchospasm. ✓ Call a code. ✓ Manage ABCs: Monitor breathing and vital signs continuously. ✓ Maintain or initiate IV access. <p style="color: red;">Prepare for intubation and resuscitation.</p>

(Continued on following page)

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	Signs and Symptoms	Treatment
Cardiovascular Reaction Bradycardia, hypotension, vasovagal reactions	Decreased heart rate (<60 bpm) and hypotension possibly accompanied by nausea, vomiting, diaphoresis, and mental status changes. Can lead to cardiovascular collapse and death if untreated.	<ul style="list-style-type: none">✓ Provide O₂ at 10–12 L/min via face mask.✓ Monitor vital signs every 5 min.✓ Administer IV fluids.✓ Atropine for vasovagal responses.
Nephrotoxic Reaction	Decreased urine output. Diagnosis of contrast-associated renal failure: serum creatinine elevation of 25% within 3 days of contrast.	<ul style="list-style-type: none">✓ Discontinue other nephrotoxic drugs if possible.✓ Space studies up to 5 days apart to allow kidneys to recover.✓ Hydrate patients 12 hr before and 2 hr after study.✓ Monitor lab values, intake, and output.
Delayed Reaction Occurs within 7 days of the injection of ICM.	Flu-like symptoms: fatigue, upper respiratory tract congestion, fevers, chills, nausea, vomiting, diarrhea, abdominal pain; pain in the injected extremity; rash; dizziness and headache; pruritus; parotitis; joint pain; constipation; and depression.	<ul style="list-style-type: none">✓ Usually resolves spontaneously with little or no treatment.

Arthrography

X-ray with contrast to examine a joint and its surrounding soft tissues (cartilage, ligaments, bursa, joint capsule). Commonly done of the knee and shoulder but hip, wrist and ankle are often done as well. **Informed consent required. Potential Complications: Infection, reaction to contrast (unlikely since contrast is not administered IV).**

PURPOSE

- Assess persistent, unexplained joint pain.
- Evaluate injuries to joint structures.
- Assess for tumor, tears, ruptures, cysts, and other abnormalities.

PROCEDURE

The patient lies supine on the x-ray table with the joint exposed. Lidocaine is injected to anesthetize the skin. Next, a needle is inserted into the joint space to aspirate synovial fluid for analysis and to minimize dilution of the contrast. The syringe is replaced with a syringe containing contrast, which is injected into the joint. To distribute the contrast throughout the joint, the patient either walks a bit or has the joint manipulated through its range of motion.

Films are taken with the joint in various positions.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about previous reactions to contrast or other risk factors for adverse reaction to contrast (see page 79).
- Inform the patient that test will take about 30 min.
- Prepare the patient to expect some discomfort when the contrast is injected.

POSTTEST CARE

- Assess vital signs and pain level.
- Assess patient for reaction to contrast (see Table, pages 81-82).
- If ordered, apply ice to joint and administer an analgesic.
- If knee has been evaluated, the patient will likely have an elastic wrap applied. Inform patient to leave wrap on per physician's order.

- Advise patient to minimize joint rotation and/or weight bearing for 1–2 days.
- Teach patient to monitor for and report signs and symptoms of infection (fever, pain, swelling warmth over joint, redness or drainage at puncture site).



Negative contrast arthrogram of the knee

Arteriogram (Angiogram, Arteriography)

*Rapid-sequence x-rays following administration of IV contrast to evaluate vascular conditions such as aneurysm, stenosis, blockage, or neoplasm. **Digital subtraction angiography (DSA)** removes the bony structures from the picture, thereby enhancing visualization. Performed in interventional radiology suite or other special procedures area. See also Cardiac Catheterization in Other Studies Tab. Common studies include:*

- ◆ **Renal arteriogram**
- ◆ **Carotid arteriogram**
- ◆ **Cerebral arteriogram**
- ◆ **Lower extremity arteriogram**
- ◆ **Pulmonary arteriogram**

Informed consent required. Potential complications include reaction to contrast, hemorrhage from arterial puncture, arterial embolism, renal failure secondary to IV contrast, stroke, thrombosis and arterial occlusion distal to puncture site, hematoma, pseudoaneurysm, neurovascular damage.

PURPOSE

- Evaluate patency, size, and shape of blood vessels.
- Assess for plaque, emboli, or other explanation for impeded blood flow.

PROCEDURE

The patient is placed supine on the x-ray table. An intravenous line, if not already present, is inserted and the patient is connected to an ECG monitor.

After prepping, a small incision is made in the groin to access the femoral artery or into the arm to access the brachial artery. Under fluoroscopy, a wire is threaded into the artery and along the arterial system until it is near or in the artery to be examined. A catheter is then threaded over the wire and the wire is removed. The contrast material is injected either by hand or with a preset automated injector while a rapid series of x-rays are taken.

The patient may receive sedation or possibly pain medication at the initiation of or during the procedure.

Throughout the procedure, the patient's vital signs are assessed and the peripheral pulses distal to the catheter insertion site are monitored.

After the study is complete, the catheter is removed and pressure is applied over the puncture site for 15 min. A pressure dressing is then applied.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about iodine or shellfish allergies.
- Check that the patient has been NPO for the prescribed amount of time (2–8 hr).
- Locate and mark peripheral pulses distal to the proposed puncture site to facilitate pulse assessment during and after angiogram. (If pulses are absent before the procedure, document this finding. Assess both by palpation and with Doppler.)
- Compare warmth, color, and strength of pulse in extremity to be used for vascular access to the nonprocedure extremity. Document preexisting differences so that postprocedure assessments can be properly interpreted.
- Check that preprocedure coagulation studies are available. If results are out of range, document and notify physician and personnel in the unit where the procedure will be performed.
- Ask if patient is taking metformin (Glucophage). Inform physician if yes and check for orders to hold the medication for 48 hr postprocedure. Ascertain that alternative to metformin has been ordered to cover blood glucose elevations.
- Assess vital signs.
- If a cerebral arteriogram is scheduled, assess the patient's neurologic status carefully to establish the baseline against which postprocedure assessments can be compared.
- Tell the patient:
 - ◆ the test takes 1–2 hr
 - ◆ there is minor discomfort associated with the insertion of the catheter but that sedative and analgesic medication will be available
 - ◆ he or she will feel a sensation of warmth when the contrast is injected but that it will only last a few seconds

- ◆ to report feelings of dizziness, itching, nausea, or other unusual feeling to radiology staff
- ◆ he or she may feel bladder fullness during the procedure secondary to the contrast's diuretic effect
- Explain postprocedure care and the importance of maintaining bedrest for several hours after the procedure.

POSTTEST CARE

- Assess the patient's distal pulses and vital signs every 15 min until stable and per facility protocol.
- Assess puncture site every 15 min for swelling, hematoma, or bleeding. Assess if pressure dressing is intact. Apply sandbag to site. Report bleeding or disruption of pressure dressing immediately. **👉 If site is bleeding, call physician immediately and apply strong pressure with both hands until help arrives.**
- Assess neurovascular status of extremity: In addition to palpating peripheral pulses, note skin temperature, color, and capillary refill time; ask about pain, numbness, or tingling; have the patient demonstrate mobility of hand or foot (depending on puncture site) without flexing or extending the extremity.
- Continue to monitor the patient for several hours. Assist patient to stand and walk when ambulation can be resumed.
- For the patient who will be discharged to home following the procedure, explain that he or she must monitor the puncture site for bleeding, pain, swelling, and abnormal skin color or temperature change in the arm or leg.
- Advise the patient not to engage in strenuous activity for 12–24 hr and not to take a hot bath or shower.

Barium Enema (BE)

X-ray and fluoroscopy of the colon after instillation of barium sulfate to enhance images. Fluoroscopy is used to visualize the barium as it moves through the large intestine. Air may be insufflated into the colon to provide additional contrast and make the mucosa more visible. **Potential Complication: retained barium in the colon causing obstruction or impaction.**

PURPOSE

- Assess for tumor, polyps, inflammatory disorder, cause of rectal bleeding, change in bowel habits, stricture, tumor, diverticula, and megacolon.
- **BE is contraindicated in patients with suspected bowel perforation. In this case, evaluation of the large intestine is accomplished using water-soluble ICM such as Gastrografin and no bowel prep.**

PROCEDURE

The patient lies on the x-ray table for a plain film of the abdomen. Next, barium is instilled into the colon using a rectal tube or, if the barium is administered through an ostomy, a Foley catheter. Transit of the barium through the large intestine into the terminal ileum is observed under fluoroscopy. Spot films from various views and with the patient in different positions are taken of significant findings. After all films are taken, the barium is aspirated from the colon and the rectal tube is removed. The patient will expel residual barium. An additional film is taken after the evacuation of barium.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- The patient will have a clear liquid diet the evening before the test and nothing by mouth, including medication, after midnight.
- The patient should drink plenty of fluids the day before the test.
- The day before the test, the patient will begin the bowel prep, which involves drinking magnesium citrate or other product in the afternoon and taking bisacodyl tablets (usually three 5-mg tabs) in the early evening.

- The morning of the test, the patient will use a bisacodyl suppository and/or a cleansing enema until the returned material is clear of fecal matter.
- The patient should be told that the instillation of the barium (and air, if used) can cause cramping and bloating.
- Reassure patient that radiology staff know that most people find the test embarrassing and will help the patient be as comfortable as possible.
- Inform the patient that testing will take 45–90 min.

POSTTEST CARE

- Assess for dehydration or electrolyte imbalance, especially in older adults.
- Retained barium can cause an impaction or obstruction. The patient should take a mild laxative or an enema to ensure that no barium is retained. Stool may appear light colored for a few days.

Barium Swallow

X-ray with contrast medium (barium solution) to enhance images of the esophagus (also called esophagography). A water-soluble iodinated contrast medium (ICM) such as Gastrografin may be used if perforation or obstruction is suspected since barium, if deposited in the soft tissues, can cause a serious inflammatory response.

PURPOSE

- Assess for anatomic deformity, stricture, tumor, foreign body, reflux disease, swallowing disorder, esophageal spasm.
- Evaluate epigastric pain or regurgitation.

PROCEDURE

A plain film is taken with the patient standing or lying supine on the x-ray table. The patient then stands in front of a fluoroscopy screen and swallows the contrast. The structure and function of the esophagus are evaluated and spot films may be taken. The patient is then strapped to the x-ray table and the table is tilted in various positions as additional films are taken.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about iodine or shellfish allergies if ICM will be used.
- The patient will be NPO for 8 hr prior to the procedure.
- The patient will have to remove jewelry from the head and neck.
- Although the procedure is not painful, some patients may not like drinking the contrast media.

POSTTEST CARE

- If the patient has had barium: inform the patient that a mild laxative and extra fluids will help with the elimination of the barium. Inform the patient that stools will appear white or light colored. Instruct patient to notify health care provider if constipated.
- If the patient has had an ICM (iodinated contrast medium): Monitor for anaphylactic, cardiovascular, nephropathic, or delayed reactions to contrast. See preceding Table, Reactions to Iodinated Contrast Media (ICM). Inform patient that some patients experience diarrhea from water-soluble ICM.

Cystography (Cystourethrogram, Voiding Cystourethrogram, Cystogram)

X-ray and fluoroscopy with contrast medium to visualize bladder and urethra structure and function. (Also see Nuclear Cystogram in Nuclear Studies Tab.) **Informed Consent required.** **Potential Complications:** UTI, reaction to contrast (unlikely since contrast is not administered IV).

PURPOSE

- Evaluate structure and excretory function of the bladder and urethra
- Assess for vesicoureteral reflux.
- Detect obstruction to urine flow (stones, stricture, stenosis, prostatic enlargement).
- Evaluate cause of recurrent UTI.

PROCEDURE

The patient is placed supine or in the lithotomy position on the x-ray table. A catheter is placed and approximately 300 mL (adult dose) of contrast material is instilled into the bladder. X-rays are taken of the bladder while it is filled with contrast. If a voiding cystourethrogram is ordered, the catheter is then removed and the patient voids while more films are taken.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about previous reactions to contrast or other risk factors for adverse reaction to contrast (see page 79).
- Inform the patient that test will take about 30 min.
- Explain that patient will feel a brief sensation of pushing when catheter is inserted.

POSTTEST CARE

- Assess patient for reaction to contrast.
- Monitor urine output and inform patient to monitor at home.
- Tell patient to drink plenty of fluids unless contraindicated.
- Assess for signs/symptoms of UTI and inform patient to report fever, malaise, frequency, urgency, bladder or flank pain.

Enteroclysis (Small Bowel Enema)

Fluoroscopy and spot x-rays with contrast (barium) to visualize the small bowel. Requires duodenal intubation. **Informed Consent required. Potential Complications: complication of intubation or sedation, retained barium.**

PURPOSE

- Evaluate persistent nausea and vomiting.
- Assess for stricture, fistula, inflammation, obstruction, tumors, or intestinal motility problems

PROCEDURE

The patient may have an IV placed and be sedated for the procedure.

The patient sits for placement of the duodenal tube. An anesthetic gel is applied to the tube and the inside of the nostril. The tube is advanced down the esophagus and into the stomach while the patient swallows. The patient is then placed supine, and the position of the tube is checked with fluoroscopy. A guide wire is placed down the tube so that it can be advanced into the pyloric sphincter and the duodenum. After proper placement of the tube, barium is infused into the tube and the progression of the barium is observed with fluoroscopy. The patient may need to assume different positions. Several spot films are taken.

PRETEST PREPATION

- The patient usually will need to be on a clear liquid diet for at least 24 hr prior to the test.
- A laxative and/or enema the evening before or the morning of the test are also usually required.
- Inform the patient that the test is not painful but that some discomfort may be experienced when the tube is inserted.
- Inform the patient that the test can take up to 6 hr to complete.

POSTTEST CARE

- Monitor vital signs and recovery from sedation (if used).

- Retained barium can cause an impaction or obstruction. The patient should take a mild laxative or an enema to ensure that no barium is retained.
- Inform the patient that stool may appear light colored for a few days.
- Patients with chronic constipation should take a mild laxative for several days until stool color returns to normal.

Hysterosalpingogram

X-ray and fluoroscopy with contrast to visualize uterine cavity and fallopian tubes. **Potential Complications: Infection, perforation of the uterus, reaction to contrast (unlikely since contrast is not administered IV).**

PURPOSE

- Assess patency of fallopian tubes and structural integrity of uterus.
- Detect displaced IUD, tubal pregnancy.
- Assess cause of repeated miscarriage.

PROCEDURE

The patient lies on the table in the lithotomy position. A speculum is placed in the vagina to visualize the cervix. A flexible catheter is placed through the cervical opening into the uterine cavity.

Contrast is slowly injected through the catheter into the uterus. An x-ray is taken as the uterine cavity is filling. Additional contrast is injected so that the fallopian tubes fill and more x-rays are taken including an oblique view.

Once the instruments are removed, the patient remains on the table for several minutes until cramping subsides.

PRETEST PREPARATION

- Ascertain that the patient is not pregnant and that last menstrual period occurred 7–10 days prior to test date.
- Inform the patient that testing takes approximately 30 min.
- Prepare the patient to expect mild to moderate cramping, which can be relieved with medications.

- Some radiologists request a bowel prep (laxative the evening before, suppository or enema in the morning) and/or a cleansing douche
- A pretest sedative such as oral diazepam may be given.

POSTTEST CARE

- Assess vital signs, pain level, amount and characteristics of vaginal discharge.
- Some women experience dizziness; assess patient for dizziness.
- Most women experience cramping for several minutes after the procedure, but some may have cramps for several hours. A mild analgesic such as ibuprophen can be given.
- Teach patient to assess for and report signs or symptoms of infection such as fever, pelvic pain and tenderness, or purulent discharge.
- Teach patient to assess for and report signs or symptoms of uterine perforation: abdominal pain and distension, vaginal bleeding, signs and symptoms of peritonitis.
- Tell the patient to expect to have vaginal discharge for a few days after the test. This discharge is the contrast agent and is harmless. It may be blood tinged but should not be frankly bloody.

Myelogram

X-rays and fluoroscopy with contrast to provide visualization of the spinal subarachnoid space and the spinal canal. Myelography is often combined with computed tomography (CT scan), which is then called CT myelography. Magnetic resonance imaging (MRI) has replaced myelography for many indications. **Informed consent required. Potential Complications: Severe headache; CSF leak; brain herniation; seizures; meningitis; puncture of the spinal cord, aorta, or vena cava; severe reaction to contrast.**

PURPOSE

- Assess signs and symptoms consistent with narrowing of the spinal canal.
- Assess patients with peripheral neurologic deficits.
- Detect spinal stenosis, herniated disk, tumor, or infection.
- Assess changes in bone structure caused by arthritis or ankylosing spondylosis

PROCEDURE

The patient is placed prone or in a side-lying position for lumbar puncture. Under fluoroscopy to verify proper placement, a needle is inserted and 15 mL of cerebrospinal fluid (CSF) is removed. The patient is positioned prone and secured to the x-ray table with straps. Then 15 mL of water-soluble contrast agent is then injected into the spinal canal and the x-ray table is tilted to distribute the contrast. Progress of the contrast is fluoroscopically observed. Lesions or obstructions to flow are apparent and spot films are taken. After all views are obtained, the needle is removed and the site is dressed.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about previous reactions to contrast or other risk factors for adverse reaction to contrast (see page 79).
- In addition to other medical history questions, ask the patient about history of seizures or use of medications that can lower seizure threshold. Ascertain that patient has discontinued seizure threshold-lowering drugs for 48 hr before the test (see Table below).

- In addition to drugs that lower the seizure threshold, anticoagulants should also be withheld for 48 hr before myelography.
- Foods and fluids restrictions vary with the type of contrast used. Some patients will be NPO for 8 hr prior to the procedure and will require a laxative or enema. Some patients may have clear liquids before the test and no bowel prep. Check with the radiology department for details.
- Let the patient know that some patients experience discomfort during the study and that sedative or analgesic medication will be provided if necessary.
- Inform the patient that an IV may be placed and fluids or medications (sedatives or anticonvulsants) may be given.
- Have the patient void before the test.
- Tell the patient that the test takes 45 min (longer if combined with CT scan) and that he or she will be monitored in the radiology department or the hospital for several hours after the procedure.

POSTTEST CARE

- Proper positioning of the head after myelogram is very important in preventing a headache. If an oil-based contrast material was used (rare), the patient must remain flat in bed for 24 hr.
- If a water-based contrast material was used, the patient must remain in bed for 24 hr, but the head of the bed can be elevated 15–30 degrees.
- Assess vital signs, neurologic status, and pain level every 30 min for 4 hr, then every 4 hr for 24 hr.
- Assess for numbness, tingling, or diminished mobility of lower extremities.
- Assess patient's ability to void.
- Encourage fluid intake to help excrete contrast.
- Assess puncture site for bleeding or drainage.
- Assess patient for reaction to contrast (see Table, pages 81-82).
- Document and report any postprocedure problems promptly.

Medications That Lower Seizure Threshold and May Be Withheld for 48 Hr Prior to a Myelogram

amitriptyline	meperidine
amitriptyline/chloridiazepoxide	mesoridazine
amitriptyline/perphenazine	methamphetamine
amoxapine	methylphenidate
amphetamine	mirtazapine
amphetamine mixture	molindone
bupropion	nefazodone
chlorpromazine	nortriptyline
clomipramine	olanzapine
clozapine	paroxetine
cycloserine	perphenazine
cyclosporine	pimozide
desipramine	prochlorperazine
dextroamphetamine	promazine
doxapram	protriptyline
doxepin	quetiapine
ephedrine	riperidone
fentanyl	sertraline
fluoxetine	theophylline
fluphenazine	thioridazine
fluvoxamine	thiothixene
haloperidol	trazodone
imipenem-cilastatin	trifluoperazine
imipramine	triflupromazine
lithium	tramadol
loxapine	trimipramine
maprotiline	venlafaxine

Operative or T-Tube Cholangiogram

X-ray and fluoroscopy of the common bile duct using an iodinated contrast medium (Hypaque) to enhance visualization. Done during gallbladder surgery or 7–10 days after cholecystectomy. **Informed Consent required. Potential Complications: severe adverse reaction to contrast.**

PURPOSE

- Evaluate biliary duct patency before removal of T-tube or, if performed during surgery, to visualize biliary tree and thus minimize risk of operative injury to the common bile duct.
- Assess for strictures, gallstones, fistula, or tumor.

PROCEDURE

T-Tube Cholangiogram: The T-tube is clamped, usually the day before the procedure. In the radiology department, the patient is placed on the x-ray table. The T-tube is unclamped and contrast medium is injected into it. The contrast is visualized with fluoroscopy as it moves through the duct system. The tube is clamped while various pictures (prone, side-lying, erect) of the right upper quadrant (RUQ) are taken.

Intraoperative cholangiogram: During surgery a catheter is inserted into the common bile duct. Contrast is injected into the catheter and x-rays are taken.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about iodine or shellfish allergies if ICM.
- T-tube cholangiogram: NPO for 1 meal prior to test. Administer an enema 1 hr before test.
- Tell the patient that he or she may experience pressure as the contrast is injected. Some patients may experience nausea, vomiting, cramps, or diarrhea from the contrast.
- Inform the patient that testing usually takes about 30 min.

POSTTEST CARE

- Monitor for anaphylactic, cardiovascular, nephropathic, or delayed reactions to contrast. See preceding Table, Reactions to Iodinated Contrast Media (ICM).

- Monitor for dehydration or electrolyte imbalance if patient experiences vomiting and/or diarrhea.
- Check if T-tube has been removed (if postop findings are normal). Apply a dry sterile dressing to the site.
- Check orders to see if T-tube is to be left clamped or unclamped.
- Assess T-tube insertion site for pain or swelling.

Oral Cholecystogram (OCG)

X-ray of the gallbladder with iodinated contrast medium (Telepaque or Oragrafin) to enhance visualization. Infrequently used since ultrasound, CT scan, and nuclear scans give better results (refer to appropriate Tabs). **Informed Consent required.**
Potential Complication: severe adverse reaction to contrast.

PURPOSE

- Assess RUQ/epigastric pain and other symptoms associated with gallbladder disorders.

PROCEDURE

After proper preparation the evening before the test (see below), the patient lies on the x-ray table while pictures are taken from varying views. The patient may be given a high-fat meal to stimulate gallbladder contractions, which are observed with fluoroscopy. Additional films are taken as the contrast moves through the common bile duct.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about iodine or shellfish allergies.
- The patient will eat a low-fat meal the evening before the test and will be NPO after midnight.
- The patient will take six Telepaque tablets 5 min apart 2–3 hr after the evening meal.
- An enema may be prescribed the morning of the test.
- Although the procedure is not painful, some patients may experience nausea, vomiting, cramps, or diarrhea from the contrast.
- Inform the patient that testing may take up to 2 hr.

POSTTEST CARE

- Monitor for anaphylactic, cardiovascular, nephropathic, or delayed reactions to contrast. See preceding Table, Reactions to Iodinated Contrast Media (ICM).
- Monitor for dehydration or electrolyte imbalance if patient experiences vomiting and/or diarrhea.

Percutaneous Transhepatic Cholangiogram (PTC)

Fluoroscopic visualization of the bile ducts with spot films of significant findings. Performed in interventional radiology. Contrast medium is administered through a fine needle inserted through the skin into the liver and into a bile duct.

Informed consent required. Potential complications: sepsis, bleeding, peritonitis, severe adverse reaction to contrast.

PURPOSE

- Distinguish between obstructive and nonobstructive jaundice and pancreatitis.
- Assess patients in whom ERCP (see Scopes Tab) has been unsuccessful.
- Assess cause of obstructive jaundice.
- Evaluate persistent upper abdominal pain after cholecystectomy.
- Establish external drainage of the biliary system as a palliative measure for patients with nonresectable malignant disease.

PROCEDURE

The patient lies on the x-ray table. A peripheral IV line is inserted and a sedative and/or pain medication are administered (sometimes a sedative is administered before the test). A local anesthetic is administered into the right upper abdominal wall. The patient holds his or her breath and a fine needle is inserted between the 10th and 11th intercostal space, midclavicular line. The needle is advanced until it enters a bile duct, after which the introducer is removed and contrast medium is injected into the biliary system.

The movement of the contrast through the bile ducts is observed on the fluoroscope, which shows whether the bile moves freely

or is obstructed. The patient is helped to assume a variety of positions while spot films are taken. After all films have been taken, the contrast is aspirated from the biliary ducts, the needle is removed, and a dry sterile dressing is applied. A catheter may be left in place if external biliary drainage is required.

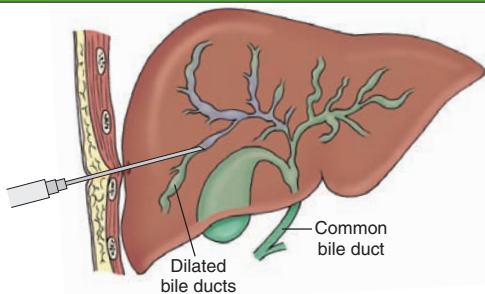
PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Check that patient has been NPO for 8 hr and clotting times, PT, and platelet count results are normal and available on the chart.
 - ✋ **Coagulation studies are frequently abnormal in patients with liver disease.**
- Make sure that pretest antibiotics have been administered.
- Ask patient about previous reactions to contrast or other risk factors for adverse reaction to contrast (see page 79).
- Ascertain that within the preceding week the patient has not taken NSAIDs, aspirin, or medications that affect bleeding times.
- Administer pretest sedative, if ordered.
- Explain that the patient may feel discomfort when the needle penetrates the liver, pressure, or brief discomfort in the right subscapular area. Reassure the patient that medication will be given to enhance comfort.
- The patient will need to remain still and hold his or her breath for short periods during the test.
- Tell the patient testing usually takes between 30 and 60 min.

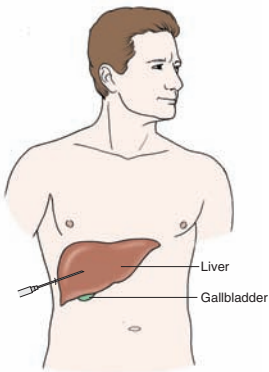
POSTTEST CARE

- Monitor for anaphylactic, cardiovascular, nephropathic or delayed reactions to contrast. See preceding Table, Reactions to Iodinated Contrast Media (ICM).
- Assess vital signs frequently according to policy.
- The patient should maintain bedrest for 6 hr postprocedure.
- Monitor for bleeding from puncture site, swelling around puncture site. Notify physician or NP immediately if the patient has right abdominal or shoulder pain (indicates bleeding), fever, dizziness, drop in blood pressure, tachycardia, or heme + stool.
- Continue antibiotics on schedule.

PTC Approach



Percutaneous transhepatic cholangiogram.



Needle insertion site for percutaneous transhepatic cholangiogram.

Pyelogram, Antegrade and Retrograde

Retrograde or antegrade pyelography is performed when IVP results are inadequate or IVP is contraindicated. **Informed Consent required. Potential Complications: severe adverse reaction to contrast; adverse reaction to anesthesia, other risks of surgery (retrograde pyelogram).**

Antegrade Pyelogram Procedure and Care

	Procedure	Pre- and Posttest Care
Antegrade Pyelogram <i>Visualizes stones, tumors, obstructions in the urinary system. Performed in interventional radiology.</i>	<p>Kidneys are located by US or CT; overlying skin is cleaned with antiseptic and local anesthetic is injected.</p> <p>Under fluoroscopy, a needle with a manometer attached is inserted into the kidney and pressure readings are taken.</p> <p>Contrast is injected into the kidney.</p> <p>X-rays are taken of kidney's upper- collecting system.</p> <p>A nephrostomy tube may be left in the kidney for drainage.</p>	<ul style="list-style-type: none">✓ Follow preoperative orders regarding bowel prep and NPO status.✓ Patient will require standard post-procedure assessment and VS monitoring.✓ Monitor needle insertion site for bleeding or hematoma. Provide nephrostomy tube care, if indicated.✓ Monitor fluid intake and urinary output for at least 24 hr.✓ Assess urine for blood.✓ Call physician or NP if patient has not voided within 8 hr of the procedure, if bladder is distended or painful, or if voiding small amounts.✓ Assess for signs of infection, such as chills, fever, and hypotension.

Retrograde Pyelogram Procedure and Care

Retrograde Pyelogram

(Retrograde: moving backward against usual direction of flow)

Visualizes stones, tumors, obstructions in the urinary system. Performed in the OR under general anesthesia in conjunction with cystoscopy.

Two catheters are inserted through the cystoscope into the ureters.

Contrast is injected into the ureters and kidney.

Contrast is observed under fluoroscopy and x-rays of the entire urinary tract are taken.

- ✓ Follow preoperative orders regarding bowel prep and NPO status.
- ✓ Patient will require standard postoperative assessment and vital sign monitoring.
- ✓ In addition:
- ✓ Monitor fluid intake and urinary output for 24 hr.
- ✓ Assess urine for blood.
- ✓ Call physician or NP if patient has not voided within 8 hr of the procedure, if bladder is distended or painful, or if voiding small amounts frequently.
- ✓ Assess for signs of infection, such as chills, fever, and hypotension.

Pyelogram, Intravenous (IVP, Excretory Urogram, EU, ExU)

X-ray with contrast medium to visualize the kidneys, renal pelvis, ureters, and bladder. Also called excretory urography (ExU) or IV urogram (IVU). Being replaced by CT urogram (see CT Tab)

Informed Consent required. Potential Complications: severe adverse reaction to contrast.

PURPOSE

- Evaluate structure and excretory function of the renal system.
- Assess patients with flank/kidney pain.
- Assess for kidney stones.
- Investigate cause of hematuria.
- Evaluate suspected obstruction, structural abnormality, or trauma to the urinary system.

PROCEDURE

The patient is placed supine on the x-ray table and an abdominal flat plate is taken to determine if any barium, stool, stones, or gas will obscure visualization. Next, an IV line is inserted and the contrast is injected. The contrast reaches the kidneys via the bloodstream, where it is filtered out of the blood and excreted through the ureters into the bladder. Films are taken approximately every 5 min until the contrast reaches the bladder. These x-rays reveal tumors, cysts, stones, or other structural and functional abnormalities. Once the contrast reaches the bladder, the patient is asked to void and another film is taken. This will reveal if the bladder empties completely.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about previous reactions to contrast or other risk factors for adverse reaction to contrast (see page 79).
- The patient should be well-hydrated and should increase fluid intake the day before the test. Check BUN; if elevated, notify radiologist.
- The patient will not be allowed foods in the 8 hr preceding the test and may be NPO. In some cases, the patient may have a clear liquid breakfast.

- A bowel prep may be ordered the evening before or the morning of the test.
- Ascertain that patients on metformin (Glucophage) have withheld the medication the day of the test.
- The patient should void immediately before the test.
- Inform the patient that the test will take 30 to 60 min.

POSTTEST CARE

- Monitor for anaphylactic, cardiovascular, nephropathic, or delayed reactions to contrast. See preceding Table, Reactions to Iodinated Contrast Media (ICM).
- Ensure adequate oral or IV hydration.
- Monitor urine output and inform patient to monitor at home.
- Ensure that renal function is evaluated before metformin is resumed 48 hr after the test.
- Patient may resume pretest activity level and diet.

Upper GI Series (UGI)

X-ray and fluoroscopy with contrast medium (usually barium sulfate) to enhance images of the lower esophagus stomach, duodenum, and upper jejunum. Allows visualization of the digestive system at work as barium moves through it. A water-soluble iodinated contrast medium (ICM) such as Gastrografin may be used if perforation is suspected since barium, if deposited in the soft tissues, can cause a serious inflammatory response. When combined with evaluation of the entire small bowel is called UGI with small bowel follow-through.

PURPOSE

- Assess for ulcers, stricture, tumor, reflux disease, hernia, and inflammation.

PROCEDURE

The patient sits or stands behind the fluoroscopy machine and is asked to swallow the barium (8–16 oz). Passage of the barium through the upper GI tract is filmed as the patient drinks. After ingestion of the barium, x-ray images are obtained with the patient in different positions (supine, side-lying, prone) and from different views (PA, AP, lateral, and oblique).

If needed, enhancement of the structures can be obtained by having the patient swallow baking soda crystals or drink barium through a perforated straw (called double-contrast). The air smooths out the gastric rugae (wrinkles and folds), which makes the anatomy clearer.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about iodine or shellfish allergies if ICM will be used.
- The patient will be NPO for 8 hr prior to the procedure.
- The patient will have to remove jewelry on the trunk, head, or neck. If jewelry has psychological or spiritual significance, the patient may hold the jewelry during the procedure.
- Although the procedure is not painful, some patients may not like drinking the barium.
- Inform the patient that testing may take up to 5 hr, although the study usually is completed within 2 hr.

POSTTEST CARE

- *If the patient has had barium:* inform the patient that a mild laxative and extra fluids will help with the elimination of the barium. Inform the patient that stools will appear white or light colored. Instruct patient to notify health care provider if constipated.
- *If the patient has had an ICM (iodinated contrast medium):* Monitor for anaphylactic, cardiovascular, nephropathic, or delayed reactions to contrast. See preceding Table, Reactions to Iodinated Contrast Media (ICM). Inform patient that some patients experience diarrhea from water-soluble ICM.
- Instruct the patient to notify health care provider if constipated.

Venogram, Lower Extremity

X-ray with contrast to enhance visualization of venous system. Requires informed consent. **Potential complications: severe adverse reaction to contrast, renal failure, dislodgement of venous thrombi.**

PURPOSE

- Detect deep vein thrombosis (DVT)

PROCEDURE

The patient is placed on the x-ray table, which is tilted at an angle between 30 and 45 degrees.

A tourniquet is placed above the ankle and sometimes on the thigh. (This is to diminish blood flow in the peripheral veins thereby allowing contrast to fill the deep veins.) An IV is started in the foot and the contrast medium is injected over 2–4 min. A series of x-rays are taken as the contrast moves through the veins. Alternatively, the progression of the contrast can be viewed using fluoroscopy with spot films taken as needed.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about iodine or shellfish allergies if ICM will be used.
- The patient may be asked to take only clear liquids for 2 hr prior to the procedure.
- Although the procedure is not painful, some patients may have mild discomfort as the catheter is inserted.
- Inform the patient that testing takes 30–90 min.

POSTTEST CARE

- Assess patient's vital signs after the procedure. Monitor for reaction to contrast.
- Encourage fluids.
- Observe puncture site for bleeding, hematoma, signs or symptoms of infection.

COMPUTED TOMOGRAPHY (CT SCANS)

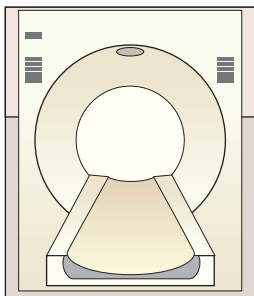
Overview of CT Scanning

- A CT scan is a specialized x-ray that takes cross-sectional pictures of all types of tissue.
- CT scans are sometimes called CAT scans. The “A” refers to the word axial, which is a particular orientation of the image. Other orientations are available now, so the A has been dropped.
- It is used extensively in diagnosing disease and injury of the:
 - ◆ Brain, cerebral blood vessels, eyes, inner ear, and sinuses.
 - ◆ Neck, shoulders, cervical spine, and blood vessels.
 - ◆ Chest, heart, aorta, lungs, and mediastinum.
 - ◆ Thoracic and lumbar spine.
 - ◆ Upper abdomen, liver, kidney, spleen, and pancreas.
 - ◆ Skeletal system including bones of the hands, feet, ankles, legs and arms, and jaws.
 - ◆ Pelvis and hips, reproductive system, bladder, and GI tract.
- It is also used to diagnose cancers, including lung, liver, and pancreatic cancer and measure tumor size and assess involvement in other nearby tissues.
- **Fluoroscopic CT** imaging is used to guide minimally invasive procedures such as:
 - ◆ Drainage of fluid collections (cysts, abscesses, lymphoceles, hematomas).
 - ◆ Biopsy.
 - ◆ Injection of pain medications into a spinal disc space.
 - ◆ Dynamic study of knee or elbow motion, swallowing, or study of the larynx.
 - ◆ Embolization to stop bleeding, for example, after liver or spleen trauma.
- **Computed tomography angiography (CTA)** is a less invasive method for examining blood vessels.
- Patients over 300 lb may be unable to undergo CT scanning.
- It is important that patients lie very still during imaging. Any motion will blur the images necessitating repeat scans.
- The CT scan itself usually takes only a few minutes to complete but the patient should allow up to 2 hr for the test.

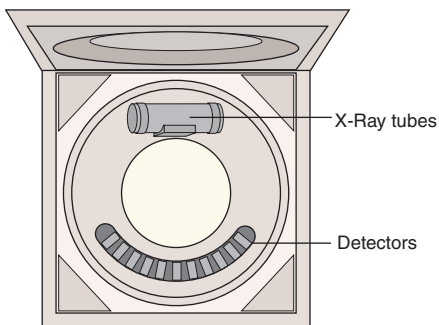
How CT Scans Work

- A CT scanner can be described as a square doughnut because of its shape (square) and the large opening in the center.
- During the scan the patient lies on the CT table, which is advanced into the opening incrementally (in fractions of an inch) so that the scanner can take a series of images.
- Inside the ring-shaped scanner are the x-ray tube and the detector. (See Figures.) The detector takes the place of film used in conventional x-rays. The x-ray tube and the detector are mounted opposite each other on the circular, rotating frame.
- To obtain the CT image “slice,” the frame rotates and the x-ray tube and the detector spin around the patient.
- Each time the x-ray tube and detector make a complete 360-degree rotation, hundreds of snapshots are obtained. These snapshots are then reconstructed by a computer into a two-dimensional image of the slice of tissue that was scanned. (See Figures.)
- The slices can be from 1–10 mm thick. The thickness is controlled by lead shutters called the collimator.
- The CT computer can detect over 200 shades of gray and can therefore better distinguish different types of tissue. A conventional x-ray can detect only 30 shades of gray.
- The images can also be enhanced with contrast media or manipulated to provide a three-dimensional display.
- A **3D-CT scan** takes many more x-ray images in smaller sections and at many different angles.
- Spiral or helical CT scans are capable of imaging entire anatomic regions in 20–30 sec.
- This is made possible by having a rotating frame that doesn’t have to stop and restart for each new 360-degree slice.
- Multislice CT spiral scanners collect more slices and more data than other spiral scanners and can present even better images.

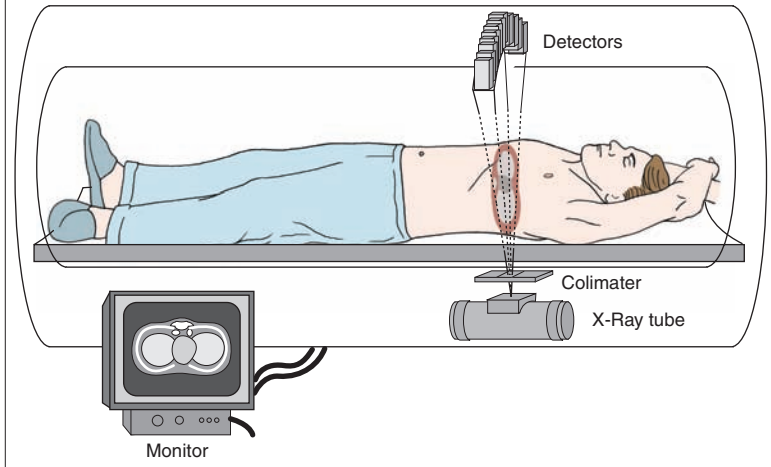
Exterior of a CT Scanner



Interior of a CT Scanner



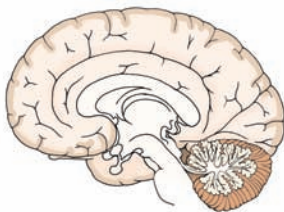
How the CT Image Is Obtained



Views



Axial view



Sagittal view



Coronal view

Sagittal, coronal, and axial views.

Radiation Exposure During CT Scans

- CT studies expose the patient to significantly more radiation than conventional x-rays. For example, a chest CT can expose the patient to 100 times more radiation than a plain x-ray.*
- Pregnant women should not undergo CT scanning because of potential damage to the fetus.
- Lead shields are used to protect reproductive organs from radiation exposure.
- **Pediatric patients are often exposed to much higher doses than necessary because default settings are intended for adults.****
 - ◆ Excessive exposure to radiation during childhood can lead to cancer later in life.
 - ◆ Scanning protocols should be adjusted for each child's weight and body type.
 - ◆ Health care providers should weigh the risks and benefits of using CT scans in children, especially when multiple CT scans are anticipated.

CT Scans with Contrast Media

- CT scan studies may be enhanced with contrast agents.
- CT contrast agents are used to make organs, blood vessels, and/or tissue types appear whiter to better show neoplasm, disease, or injury. See next page for overview of contrast and refer to pages 78-82 in Tab 3 for a complete discussion of contrast media, its uses, and risks.
- Contrast can be administered intravenously, orally, rectally, or by inhalation, which is called **Xenon CT** (for the name of the gas inhaled and is used for lung and brain imaging).
- In studies of pelvic organs, patients may receive IV, oral, and rectal contrast.

*Source: RSNA News - August 2004 Patients and Physicians Uninformed About CT Risks.

http://www.rsna.org/publications/rsnanews/aug04/ct_dose-1.html. Accessed 8/28/04

**Source: Studies Find Radiation Doses From CT Scans Often Too High For Children. <http://imagingis.com/ct-scan/news/news1.26.01.asp>. Accessed 8/28/04

IV CONTRAST

- Associated with greater risk of reaction than other routes.
- Given to visualize blood vessels and tissues such as brain, spine, liver, and kidneys.
- Administered by loading into a power-assisted injector, which automatically administers the contrast.
- Total volume of contrast injected ranges from 75–150 mL.
- Patients may experience a warm feeling and a metallic taste when contrast is injected, which is harmless.
- Patients may also experience mild itching, hives, nausea, vomiting, or dizziness, which can be treated with antihistamines.
- Other reactions include cardiovascular, nephropathic, or delayed responses or severe anaphylactoid responses.
- 🚫 **Studies using IV contrast can only be performed after obtaining informed consent.**
- 🚫 **Assess renal function studies. Report elevations in BUN/creatinine to physician and radiology staff.**
- **Determine if patient takes metformin (Glucophage), which must be withheld for 48 hr after administration of IV contrast.**

ORAL CONTRAST

- Barium and Gastrografin are the contrast agents used to enhance images of the abdomen and pelvis.
- Barium is the most commonly used agent. It has a milk shake–like consistency and is flavored to enhance palatability.
- Gastrografin has the consistency of water. It is an iodinated contrast medium (i.e., it contains iodine).
- Patient preparation varies but usually involves restriction of food and fluids for several hours prior to testing.
- Patients usually drink 1000–1500 mL of contrast.

RECTAL CONTRAST

- Barium or Gastrografin is also administered rectally when CT scanning the large intestines or pelvic organs.
- It is administered in the radiology department.
- After the study is complete, the contrast is drained out of the large intestine.
- Preparation involves restricting foods and fluids and taking laxatives and/or cleansing enemas before testing.

Patient Preparation for CT Scan

- Tell the patient that he or she should:
 - ◆ Wear comfortable, loose-fitting clothing if an outpatient.
 - ◆ Remove clothing, jewelry, or anything else that might interfere with imaging (belts, earrings, bra, glasses, dentures, hairpins, clothing with zippers and snaps). If jewelry has psychological or spiritual significance for the patient, it usually can be held by the patient or moved to a part the body not under examination.
 - ◆ Inform the physician of any medications that are being taken, both prescription and nonprescription.
 - ◆ Inform the physician if pregnant, diabetic, or allergic to any foods or drugs.
 - ◆ Inform the physician about previous reactions to contrast.
- Explain to the patient that he or she will:
 - ◆ Be positioned on a narrow table that slides into the scanner.
 - ◆ Be monitored by a technologist and a radiologist who will be directing the study from an adjacent room (where the monitor and computer are).
 - ◆ Be able to communicate with the technologist at all times via an intercom.
 - ◆ Experience no pain from the study, although positioning might feel a little awkward.
 - ◆ Have an IV started if contrast will be given.
 - ◆ Be asked to hold his or her breath and lie very still for up to 30 sec.
- On rare occasions, the contrast may cause a life-threatening anaphylactoid reaction manifested by laryngeal edema, shortness of breath, and hypotension. **👉 Tell the patient to alert the technologist via the intercom if he or she has trouble breathing. Tell the patient if this occurs, the exam will be stopped and medication given.**
- If scheduled for abdominal films, determine if the patient has had a barium contrast study or taken medications containing bismuth in the previous 4 days. (Films will need to be postponed until all contrast is excreted.)
- After the CT images are reviewed, the patient will be released from the imaging department or center.

Abdominal/Pelvic CT

Computed x-ray of the abdomen and or pelvic organs, usually with oral contrast and IV contrast and sometimes with rectal contrast as well. Used for looking at solid organs, such as the liver, pancreas, spleen, kidneys, adrenal glands, and pelvic organs and for evaluating the abdominal aorta and vena cava. Also used to assess lymph nodes in the abdomen. Less useful for evaluating the stomach and intestines, although the CT scan can provide some information about these structures as well. **Informed consent usually required. Potential complications: severe adverse reaction to contrast.**

PURPOSE

- Assess abdominal/pelvic pain or suspected liver, kidney, or gallbladder disease.
- Evaluate abdominal trauma.
- Assess signs of inflammation or infection inside the abdomen.
- Assess for cancer; stage or monitor tumors during therapy.

PROCEDURE

Before the procedure begins, the patient will drink the oral contrast and, if IV contrast is to be given, will have an IV placed. The patient then lies on the CT table. The technologist will help position the patient's body, if necessary, with pillows. The table will be advanced slowly into the gantry (the ring-shaped CT scanner) in millimeters as the images are taken. The technologist will tell the patient when to hold his or her breath, and will also control the position and advancement of the table. The IV contrast may be administered before or during the test.

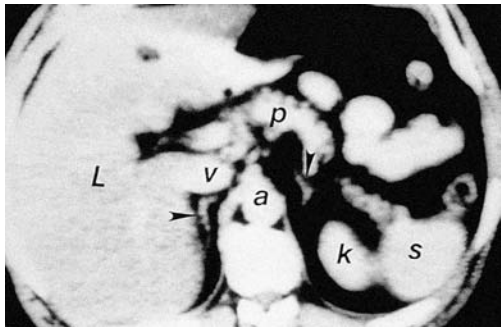
PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about previous reactions to contrast or other risk factors for adverse reaction to contrast (see page 79).
- Unless no IV contrast will be given, the patient should be well hydrated and should increase fluid intake the day before the test. Check BUN; if elevated, notify radiologist.
- Ascertain that patients on metformin (Glucophage) have withheld the medication the day of the test.
- Tell the patient the test is painless.

- Oral contrast preparation may vary, but generally the patient will be asked to drink three cups of oral contrast over a 30-min period 90 min before the CT appointment. The patient then will be given more contrast to drink in the radiology department.
- Check with the radiology department about restriction of food and fluids. Some departments ask that the patient remain NPO except for the contrast and medications while others may allow the patient to eat lightly (juice and crackers) after the initial few cups of oral contrast have been consumed at home.
- The patient should void immediately before the test.
- Inform the patient that the test will take 5–30 min.

POSTTEST CARE

- When the exam is over, the technologist will check the images while the patient waits. If no more images are needed, the patient will be discharged from the radiology department.
- If IV contrast is given, provide the patient with and encourage intake of oral fluids to help excrete the contrast.
- If oral or rectal barium was given, tell the patient that stools may appear light-colored and to inform a health care provider if constipated.
- Monitor for reaction to IV contrast.



CT scan of abdomen. Arrows point to adrenal gland. a = aorta, v = vena cava, p = pancreas, k = kidney, L = liver, s = spleen.

Angiogram, CT (CTA)

X-ray with contrast to visualize arterial blood flow of the brain, lungs, kidneys, or extremities. CT angiography is much less invasive than traditional arteriography, which involves arterial puncture and threading a catheter through the artery. In CTA, iodinated contrast is quickly injected into a peripheral vein while numerous and very thin “slices” are imaged. **Informed consent may be required. Potential complications: severe adverse reaction to contrast.**

PURPOSE

- Detect atherosclerotic disease.
- Evaluate for pulmonary embolism.
- Assess blood flow in the renal, pelvic, or carotid arteries.
- Identify aneurysms.
- Identify aortic dissection.
- Identify cerebral arteriovenous malformation.
- Evaluate stent functionality.
- Evaluate trauma patients for arterial damage.

PROCEDURE

The patient is positioned on the CT table with the body part to be examined placed inside the opening. First, a test image and small dose of contrast will be taken to determine optimal positioning and timing. Next, the contrast is loaded into an automatic injector and the contrast is administered quickly while the area is scanned.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about previous reactions to contrast or other risk factors for adverse reaction to contrast (see page 79).
- The patient should be well-hydrated and should increase fluid intake the day before the test.
- Check BUN; if elevated, notify radiologist.
- Ascertain that patients on metformin (Glucophage) have withheld the medication the day of the test.
- Tell the patient the test is painless and will take 10–20 min.

POSTTEST CARE

- When the exam is over, the technologist will check the images while the patient waits. If no more images are needed, the patient will be discharged from the radiology department.
- Provide the patient with and encourage intake of oral fluids to help excrete the contrast.
- Monitor for reaction to IV contrast.

Brain CT

Computed x-ray of the brain, usually with contrast. Images show slices of brain as though viewed from the top of the head. A xenon CT or a perfusion CT scan can reveal cerebral blood flow. Helical or spiral CT scans result in three-dimensional images that aid greatly in localizing brain tumors. ***Informed consent may be required. Potential complications: severe adverse reaction to contrast.***

PURPOSE

- Assess patients with head trauma for bleeding, brain damage, or skull fractures.
- Assess patients with stroke symptoms.
- Evaluate sinuses.
- Evaluate facial injuries and as an adjunct to planning for surgical reconstruction.
- Assess patients with neurologic symptoms including severe headache or change in mental status.
- Detect aneuysms, infection, tumor, or structural defects.
- Plan radiation therapy for brain cancer.
- Guide needle biopsies of the brain.

PROCEDURE

The patient lies supine on the CT table and the head is immobilized in a brace. An IV will be started if contrast will be used. The table is advanced into the scanner and a series of pictures are taken at different intervals and at varying levels over the head. The images are displayed on a viewing monitor and then recorded on film. IV contrast is then injected and a second series of pictures is taken.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about previous reactions to contrast or other risk factors for adverse reaction to contrast (see page 79).
- Unless IV contrast will not be given, the patient should be well hydrated and should increase fluid intake the day before the test.
- Check BUN; if elevated, notify radiologist.
- Ascertain that patients on metformin (Glucophage) have withheld the medication the day of the test.
- Tell the patient the test is painless and will take 10–20 min without contrast or up to 40 min with contrast because scans are taken before and after contrast.

POSTTEST CARE

- When the exam is over, the technologist will check the images while the patient waits. If no more images are needed, the patient will be discharged from the radiology department.
- If IV contrast was given, provide the patient with and encourage intake of oral fluids to help excrete the contrast.
- Monitor for reaction to IV contrast.



CT showing intracerebral hemorrhage within the left parietal lobe.

New Technology: CT Cerebral Perfusion Imaging

- Perfusion CT scanning is a relatively new technique that can be used to provide qualitative and quantitative information about the blood flow in the brain.
- **How it works:** Using traditional CT scanning methods and special software, the patient's brain is scanned every few seconds before, during, and after the administration of IV contrast. The data obtained are then analyzed to determine cerebral blood volume (how much blood is in the brain), the mean transit time of the blood through the cerebral capillaries, and the cerebral blood flow. Areas of interest can be isolated; for example, if the physician wants to know adequacy of blood flow from a specific artery.

Advantages

- ◆ Can be performed using standard CT scanners.
- ◆ More widely available and less expensive than MRI.
- ◆ Less invasive than CT angiography.
- ◆ Uses a relatively small amount of contrast agent.
- ◆ Other brain-scanning techniques such as PET, SPECT, or xenon CT require special equipment not found in many hospitals, cost more, or are more difficult for patients.

Applications

- ◆ Assess blood flow prior to carotid surgery.
- ◆ Assess stroke risk.
- ◆ Assess ischemic damage and potential benefit of tPA therapy.
- ◆ Assess cerebrovascular reserve (the degree to which the brain blood flow system is stressed) by administering acetazolamide to dilate blood vessels and maximize flow. Some patients' vessels don't dilate in response to acetazolamide, indicating they already are maximally dilated and letting as much blood through as possible.
- ◆ Potentially can be used to map brain tumor growth and change.

Source: Hoeffner EG et al. Cerebral perfusion CT: technique and clinical applications. *Radiology*.2004; 231: 632-644.

Chest CT

Computed x-ray of the chest, usually with contrast. A spiral CT gives better quality images in less time (20 sec), which is an important consideration for children, elderly, or critically ill patients who cannot hold their breath for a long time. **Informed consent may be required. Potential complications: severe adverse reaction to contrast.**

PURPOSE

- Follow-up to abnormal or inconclusive conventional chest x-rays.
- Evaluate signs and symptoms of disease of the chest.
- Detect and evaluate primary tumors in the lung and mediastinum or metastatic tumors from other parts of the body.
- Assess tumor response to treatment.
- Guide needle biopsy to the lung.
- Assess for pneumonia, tuberculosis, emphysema, bronchiectasis, and diffuse interstitial lung disease.
- Assess for inflammation or other diseases of the pleura.
- Evaluate patients with chest injury to assess injury to organs, bones (including the spinal column), and major blood vessels.
- Evaluate suspected aneurysm.
- Detect pulmonary emboli (see CT Angiogram [CTA]).

PROCEDURE

The patient is positioned on the table and the table is advanced into the scanner while a series of pictures are taken. The images are displayed on a viewing monitor and then recorded on film. If IV contrast is to be used, the technologist injects the contrast and a second set of pictures is taken.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about previous reactions to contrast or other risk factors for adverse reaction to contrast (see page 79).
- If IV contrast will be given, the patient should be well hydrated and should increase fluid intake the day before the test.
- Check BUN; if elevated, notify radiologist.
- If IV contrast will be used, ascertain that patients on metformin (Glucophage) have withheld the medication the day of the test.
- Tell the patient the test is painless and will take 15–30 min.

POSTTEST CARE

- When the exam is over, the technologist will check the images while the patient waits. If no more images are needed, the patient will be discharged from the radiology department.
- If IV contrast was given, provide the patient with and encourage intake of oral fluids to help excrete the contrast.
- Monitor for reaction to IV contrast.

Skeletal CT (Bones or Joints)

Computed x-ray of the bones or joints provides more detailed information than standard x-rays. Contrast material may be given with the CT scan to help define blood vessels or soft tissue areas. ***Informed consent may be required if IV contrast is given. Potential complications: severe reaction to contrast.***

PURPOSE

- Assess bones, cartilage, muscles, tendons, and joints for damage, lesions, fractures, or other abnormalities.
- Detect primary or metastatic tumors.
- Detect hidden fractures or bone infection (osteomyelitis).
- Assess difficult to evaluate joints such as the temporomandibular joint, sternoclavicular joint, or sacroiliac joint.

PROCEDURE

The patient is positioned on the CT table. An IV is started if contrast is to be given. The table is then advanced into the scanner and the tomograms are taken.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about previous reactions to contrast or other risk factors for adverse reaction to contrast (see page 79).
- If IV contrast will be given, the patient should be well hydrated and should increase fluid intake the day before the test.
- Check BUN; if elevated, notify radiologist.
- If IV contrast will be used, ascertain that patients on metformin (Glucophage) have withheld the medication the day of the test.
- Tell the patient the test is painless and will take 15–30 min.

POSTTEST CARE

- When the exam is over, the technologist will check the images while the patient waits. If no more images are needed, the patient will be discharged from the radiology department.
- If IV contrast was given, provide the patient with and encourage intake of oral fluids to help excrete the contrast.
- Monitor for reaction to IV contrast.

Spinal CT

Computed x-ray of the spine, usually with contrast IV or intrathecal contrast. A spinal CT gives better quality images in less time (20 sec), which is an important consideration for children, elderly, or critically ill patients who cannot hold their breath for a long time. Spinal CT does not always show enough detail to properly assess the spinal cord. For this reason, MRI imaging is preferred. **Informed consent may be required.**
Potential complications: severe adverse reaction to contrast.

PURPOSE

- Detect spinal damage in trauma patients.
- Detect primary or metastatic tumors in the vertebral column.
- Identify spinal stenosis (narrowing of the spinal canal), vertebral fracture, infection, or degenerative disease such as arthritis.
- Guiding diagnostic procedures such as the biopsy or aspiration of fluid from a localized infection (abscess).

PROCEDURE

The patient lies on his or her back on the CT table. An IV is started. Although pictures are taken initially without contrast, intrathecal or IV contrast is administered after the first set of pictures is taken. For intrathecal injection, the patient lies on his or her stomach or side. The injection is usually given in the lumbar spine but may occasionally be injected into the cervical spine. After skin preparation, the needle is inserted. Under fluoroscopic CT guidance, the physician injects the contrast and the needle is removed.

The patient is asked to move into different positions, or the table may be tilted at different angles to move the contrast material into the areas of interest. The table is then advanced into the scanner and the tomograms are taken.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Ask patient about previous reactions to contrast or other risk factors for adverse reaction to contrast (see page 79).
- Unless IV contrast will not be given, the patient should be well hydrated and should increase fluid intake the day before the test.
- Check BUN; if elevated, notify radiologist.
- If IV contrast will be used, ascertain that patients on metformin (Glucophage) have withheld the medication the day of the test.
- Tell the patient the test is painless and will take 15–30 min.

POSTTEST CARE

- When the exam is over, the technologist will check the images while the patient waits. If no more images are needed, the patient will be discharged from the radiology department.
- If IV contrast was given, provide the patient with and encourage intake of oral fluids to help excrete the contrast.
- For patients who have had intrathecal puncture, assess VS, sensation, and mobility in lower extremities and general neurologic status including headache, irritability, or seizure activity.
- Monitor for reaction to IV contrast.

Body CT Scan, Whole

Computed x-ray of the entire body without contrast. Whole body computed tomography (WBCT) is sometimes advocated as a screening tool, although professional organizations and the FDA generally state that no evidence exists to support the use of CT scanning on asymptomatic individuals (i.e., as a screening tool). In some imaging centers, patients can obtain a whole body scan without a physician's order. ***Informed consent is not usually required.***

PURPOSE

- Screen for disease.

PROCEDURE

The procedure is similar to all other CT scans, except that contrast is not given.

PRETEST PREPARATION

- Pretest preparation is primarily educational; for example, explaining what the machine looks like, the way to communicate with the technologist, positioning, etc.
- The patient undergoing elective WBCT should be told the limitations of the study, the risks of radiation exposure, and the possibility that benign conditions, formerly unsuspected, will require follow-up interventions to definitively rule out pathologic processes. These interventions could subject the patient to risks he or she otherwise would not have encountered.
- Follow-up may be limited to noninvasive testing or may involve invasive procedures and the risks of anesthesia. Even other radiologic exams carry risks of radiation exposure and potential allergic reaction to injected contrast material.

POSTTEST CARE

- Posttest care is also primarily educational involving explaining when test results will be available.
- The patient who has undergone a WBCT for asymptomatic screening should be reminded that normal findings carry the possibility of inaccuracy and false reassurance and that suspicious findings will require follow-up.

MAGNETIC RESONANCE IMAGING (MRI)

Overview of MRI

- MRI is a noninvasive imaging technology that gives detailed pictures of internal structures.
- MRI is used to evaluate:
 - ◆ Head trauma (assess for bleeding or swelling).
 - ◆ Neurologic symptoms suggestive of cerebral aneurysm, stroke, tumor, and suspected spinal cord lesion or injury.
 - ◆ Cardiac or major blood vessel disease (vena cava obstruction, renal vein thrombosis, renal arterial obstruction, portal vein obstruction, aneurysms).
 - ◆ Renal disease (hydronephrosis, glomerulonephritis, acute tubular necrosis).
 - ◆ Cancer of the pancreas, adrenal glands, and gallbladder.
 - ◆ Biliary disease, lymphadenopathy, and staging of prostate, uterine, or bladder cancer.
 - ◆ Musculoskeletal disorders including problems with joints, soft tissues, or bones.
- MRI generally is not helpful in evaluating small and large bowel function.
- MRI scans produce very detailed images of body structures. The images look similar to CT scan images, but MRI scans are done without using ionizing radiation. **Ionizing radiation**, which is used in conventional x-rays and CT scans, is radiation with enough energy to completely remove an electron from its orbit. Ionization can be destructive to living tissue and increases the risk of developing cancer.
- In addition to producing images of structures, MRI is also used to “see” the physiology of the body through techniques such as **functional MRI (fMRI)**. For example, fMRI can show which parts of the brain are functioning during various activities. This is accomplished by asking the patient to perform certain tasks (tapping fingers, answering simple questions) during imaging.
- **MR angiography (MRA)** produces 3-D reconstructions of blood vessels, is noninvasive, and doesn’t require contrast.
- **MR spectroscopy (MRS)** reveals the biochemistry of specific organs or tissues.

How MRI Works

- The body contains millions of hydrogen atoms in all types of tissue. MRI is based on the fact that hydrogen atoms found throughout the body in water can be affected by a magnetic field. The net result is that an MRI image shows differences in the water content and distribution in various body tissues
- The MRI machine looks like a large cylinder with a table that can advance into the bore, or opening, of the cylinder. The cylinder contains the powerful magnet.
- After proper preparation and positioning, the patient is placed in the MRI machine and into the strong electromagnetic field generated by the magnet.
- In response to this magnetic pull, the hydrogen atoms in the body align with the magnetic field, either in the same direction or opposite to the direction of the field.
- A powerful radio signal is then sent through the patient's body at the desired level (or slice). This results in the hydrogen atoms being raised to a higher state of energy.
- When the radio signal is turned off, the hydrogen atoms return to their original energy state and the extra energy, or resonance, is released in the form of radio waves.
- This resonance is picked up by radio receivers in the MRI machine and transmitted to a computer. These energy differences end up appearing as different shades of gray on the MRI image.
- Through a series of complex calculations, the computer constructs an image derived from the magnetic resonance and displays it on a screen. It is then photographed and recorded on x-ray film.
- Different tissues resonate at different frequencies, which is the basis for how the detailed images are produced.
- Current MRI machines generate these images as 3-D projections. A 3-D MRI image can be "sliced" and examined in detail, which has been described as "virtual" exploratory surgery.

Safety Issues Associated with MRI

Several injuries and a few deaths have occurred during MRI because of the powerful magnets used. Not only are the magnets capable of attracting metal objects quite a distance from the magnet, but the magnetic field also interferes with the operation of certain devices. Overall, five hazards associated with MRI have been identified:

- **Flying projectiles**—metallic objects are forcefully pulled by the magnet, becoming airborne and hurtling toward the opening of the MRI machine. Several patients have been killed or injured by oxygen tanks, scissors, IV poles, traction weights, stethoscopes, and other magnetic objects, which can reach speeds of up to 40 miles per hour.
- **Twisting or movement of metallic implants** such as aneurysm clips in response to the strong magnetic fields of the MR equipment.
- **Burns**—anything with metal in it can become hot and cause burns. Burns from various sources including contact with an electrically conductive cable, tattoos heating up due to the iron oxide content, ECG or pulse oximeter leads conducting currents, and patient contact with the magnet bore have been recorded.
- **Malfunction of devices**, including PCA pumps, ventilators, and pacemakers, leading to serious patient harm or death.
- **Undetected artifact** from various sources leading to change in MRI image and possible misdiagnosis.

🚫 **MRI is contraindicated in the presence of the following patient conditions or treatment modalities:**

- ◆ Cardiac pacemaker.
- ◆ Implanted cardiac defibrillator.
- ◆ Aneurysm clips.
- ◆ Carotid artery vascular clamp.
- ◆ Neurostimulator.
- ◆ Insulin or infusion pump.
- ◆ Implanted drug infusion device.
- ◆ Bone growth/fusion stimulator.
- ◆ Cochlear or ear implant.
- ◆ IUD or diaphragm.

MRI Contrast

- Contrast is used in MR studies to help differentiate diseased tissue from healthy tissue.
- In conventional x-rays and CT scanning, contrast media weaken x-rays as they pass through the body. In MRI, contrast works by altering the time it takes for hydrogen atoms to return to their original energy state. Because the time factor is changed, the contrast-enhanced tissues send out different signal intensities, which cause them to appear much brighter on the final image.
- Contrast also enables detection of smaller-sized tissue changes. For example, tumors $>1\text{--}2$ cm in size will show up fairly clearly without contrast, whereas contrast-enhanced studies may reveal even smaller tumors.
- Most MRI contrast media contain *gadolinium*, a heavy metal (chemical symbol Gd). Other agents, those with organ specificity, are also available.
- MRI contrast agents are administered intravenously by the MRI technician during the test. Unlike iodinated contrast agents, patients do not experience any flushing, itching, or metallic taste when MRI contrast is administered.
- Although reactions to MRI contrast are much rarer than reactions to iodinated contrast agents, the possibility of a reaction, including serious, anaphylactoid or cardiovascular reactions, should always be considered, especially in those patients with a known clinical hypersensitivity, a history of asthma, or other allergic respiratory disorders.
- Since contrast is largely excreted by the kidneys, renal function should be monitored when patients with impaired renal function receive contrast.
- Patient with sickle cell anemia and other hemoglobin disorders may have an increased risk of vaso-occlusive complications.

Pretest Patient Preparation for MRI

- Tell the patient that he or she will change into a hospital gown.
- There are no food or fluid restrictions prior to MRI. Occasionally, the patient may be asked to restrict food or fluids.
- Explain that the patient will have to remove jewelry, watch, hairpins or hair clips, keys, coins, wallet, credit cards, eyeglasses, hearing aid, removable dental work, belts and buckles, or other objects suspected of containing metal.
- The patient must be thoroughly screened for internal metallic objects. Ask the patient about prosthetic valves or joints, implanted infusion devices, shrapnel, bone screws, metal plates, etc. All imaging centers will have a screening form for this purpose that must be completed.
- Explain that the technologist will start an IV if contrast is used.

Procedure for MRI

- After positioning the patient on the table, the technologist places an apparatus called a surface coil (a special radio antenna) around the area of interest.
- The table is advanced into MR gantry (opening).
- The technologist will leave the room, but the patient can communicate with the technologist via the intercom.
- A mild sedative can be given prior to the MRI scan to help control anxiety and claustrophobia.
- The patient will hear knocking noises as the MR sequences are run. Most scans require two to six different sequences, each lasting 2–15 min.
- The patient must lie completely still during scanning.
- The MRI scanning time ranges from 30 to 90 min.

Posttest Care After MRI

- After the study is complete, the patient will be asked to wait until the images are reviewed. Once it is determined that the images are adequate, the patient can leave.
- Tell the patient when the results will be available and whom he or she should contact with questions.
- No physical posttest care is required.

Adrenal, Biliary, Brain, Chest, Kidney, Liver, Musculoskeletal, Spine, and Vascular System MRI Scans

For all the following MRI scans, refer to Pretest Preparation, Procedure, and Posttest Care on the preceding page and General Pretest Patient Education in Tools section.

MRI Scans

MRI Ordered	Indications/Comments
Adrenal glands	<ul style="list-style-type: none"> ◆ Distinguish an adrenal adenoma from a metastatic lesion. ◆ Pheochromocytomas and other paragangliomas.
Biliary system <i>MRCP—Magnetic Resonance Cholangio-pancreatography</i>	<ul style="list-style-type: none"> ◆ Identify biliary system in patients who cannot tolerate endoscopic retrograde cholangiopancreatography (ERCP). ◆ Retained gallstones, recurrent choledocholithiasis, strictures, biliary and pancreatic neoplasms, and chronic pancreatitis all may be assessed, as can fluid collections or aneurysms.
Brain	<ul style="list-style-type: none"> ◆ Tumor, infection, inflammation, trauma, stroke, multiple sclerosis, optic or auditory nerve dysfunction, change in mental status, headaches, and symptoms associated with vascular occlusion. ◆ In functional MRI (fMRI), assess the part of the brain controlling thought, speech, movement, or sensation. This is helpful in planning surgical or radiation treatment for brain lesions.
Chest	<ul style="list-style-type: none"> ◆ Lung masses. ◆ Follow-up to other diagnostic study. ◆ Assess for abnormal lymph nodes. ◆ Stage tumors.

(Continued on following page)

(Continued)

MRI Ordered	Indications/Comments
Kidney	<ul style="list-style-type: none"> ◆ Characterize mass found on other study, renal imaging for patients who can't take x-ray contrast, and assess patency of renal veins or inferior vena cava. ◆ Assess for tumor thrombus in renal cell carcinoma.
Liver	<ul style="list-style-type: none"> ◆ Ultrasound and CT are the primary imaging studies for the liver but MRI, using liver-specific contrast, can be used to diagnose atypical liver lesions, cirrhosis, tumors, and hemangiomas and to assess for portal vein patency.
Musculoskeletal structures	<ul style="list-style-type: none"> ◆ Internal derangement of the knee (meniscal injuries, ligament tears). ◆ Shoulder injuries (rotator cuff tears, tendonitis). ◆ Hip pain (osteoporosis, osteoarthritis, avascular necrosis). ◆ Assess pain, swelling, and deformity in any joint including temporomandibular joint.
Spine	<ul style="list-style-type: none"> ◆ Disc disease, spinal stenosis, tumors, infection, inflammation, and multiple sclerosis. ◆ Assess all areas of the spine—cervical, thoracic, lumbar.
Vascular system MRA—Magnetic Resonance Angiography	<ul style="list-style-type: none"> ◆ Noninvasive assessment of many vascular abnormalities. ◆ Circle of Willis, carotid arteries are the most common sites. ◆ Assess thoracic and abdominal aortic aneurysms, renal arteries, and lower extremity arteries and coarctation. ◆ Presence and extent of renal artery stenosis.

Example of an MRI Image



MRI of the cervical spine, sagittal view. Note cerebellum (A), spinal cord (B), marrow of C2 vertebral body (C), and dense intervertebral disc of C4-5(D).

New Technology: Cardiac Magnetic Resonance Imaging

MRI has been used successfully to image all areas of the body, including the heart and the vascular system. However, due to the complexities involved in imaging the beating heart, difficulties that are magnified when trying to image small coronary arteries, MRI as an aid to diagnosing coronary artery disease or heart attack is still an unrealized goal.

Nonetheless, research into enhancing the use of MRI in the diagnosis of cardiac disease, especially to diagnose it before symptoms develop, continues in many university settings.

Potential Uses of Cardiac MRI

- Diagnose heart attack in patients with chest pain.
- Diagnose coronary artery disease using a technique called "black-blood" MRI (in the resulting image, the blood appears black and the artery wall appears white).
- Identify plaques that are vulnerable to rupture.
- Assess angioplasty sites for restenosis.
- Assess the microvascular circulation of the heart.
- Replace fluoroscopy to guide procedures such as angioplasty.

Potential Advantages of Cardiac MRI

- Replace multiple other tests including cardiac catheterization, echocardiogram, MUGA scan, and thallium scan.
- Does not involve exposure to ionizing radiation.
- Does not expose the patient to iodinated contrast agents.
- Does not expose the patient to the risks associated with arterial puncture and cannulation.

Disadvantages of Cardiac MRI

- Because metal objects cannot be in the MRI scanning room, patients who require cardiac monitoring or who have stents, staples, or a pacemaker will be ineligible for the test.
- Other known disadvantages such as expense and some patients' inability to tolerate the enclosed space of the MRI.

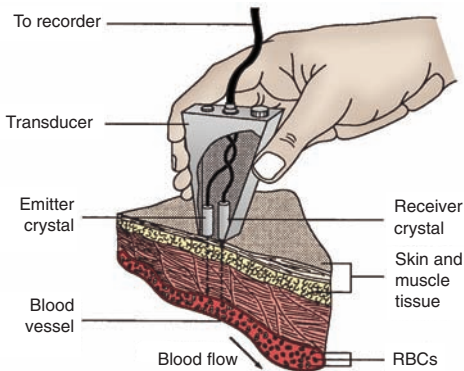
Source: Cardiac MRI - Ready for prime time? Heart Disease/ Cardiology, Richard N. Fogoros, M.D. <http://heartdisease.about.com/library/weekly/aa031201a.htm> accessed 8/1/04

ULTRASOUND (US)

Overview of Ultrasound Imaging

- An ultrasound study, also called a **sonogram**, is a noninvasive diagnostic procedure that uses sound waves to create gray-scale images of internal structures. The high-pitched sound waves cannot be heard by the human ear.
- **How it works:**
 - ◆ Ultrasound uses high frequency sound waves to obtain images of internal structures.
 - ◆ The ultrasound is produced by the transducer, which is attached to the ultrasound equipment.
 - ◆ The transducer is pressed against the skin overlying the structure to be studied. For some studies, the transducer is placed internally.
 - ◆ The transducer sends a pulse of ultrasound waves into the tissues. When the sound waves hit a boundary between tissues, the ultrasound waves bounce back as a series of echoes and are picked up by the transducer, amplified, and displayed on the monitor.
 - ◆ Using the time it takes for sound to travel through tissue and the time it takes for the echoes to return, the machine calculates the distance from the probe to the tissue or organ.
 - ◆ These distances and intensities of the echoes are displayed on the screen.
- It is used to evaluate the shape and position of organs and tissues and to detect masses, edema, stones, and displacement of tissue. In obstetrics, ultrasound is used to evaluate fetal development and well-being.
- Ultrasound is also used to guide biopsies.
- Tissues that strongly reflect ultrasound are called **hyperechoic**.
- Tissues that reflect ultrasound poorly are called **hypoechoic**.
- Fluid, which does not reflect sound, is **anechoic**.
- **Echocardiography** is ultrasound of the heart. It is used to evaluate cardiac chamber size, wall thickness, wall motion, valve configuration and motion, and the proximal great vessels.
- **Vascular ultrasonography** is ultrasound of blood vessels.

- **Conventional ultrasonography** is ultrasound of organs other than the heart such as:
 - ◆ Liver, gallbladder, and spleen.
 - ◆ Kidneys and bladder.
 - ◆ Prostate, uterus, ovaries, and breasts.
 - ◆ Musculoskeletal structures.
- **3-D ultrasound** uses special software and the 2-D images obtained from ultrasound to construct 3-D images of internal structures.
- **Doppler ultrasound** is a technique used to determine speed of blood flow through arteries and veins by converting the sound waves into audible sounds or line graphs. Doppler colorflow imaging, harmonic Doppler, and spectral Doppler are different modalities that enhance images and provide more information.



Doppler ultrasound device to detect blood flow velocity.

Pretest Preparation for Ultrasound Tests

- Many ultrasound studies require no food or fluid restrictions but some preparation may be indicated.
- Pelvic ultrasounds usually require a full bladder, so the patient may be asked to drink several glasses of water and not void before the test.
- Some abdominal ultrasounds require that the patient eat a low-fat meal or restrict intake for a few hours before the test.

Procedure for Ultrasound Tests

- The patient changes into a hospital gown and then is positioned on the exam table.
- The appropriate body area is exposed for examination.
- Acoustic conducting gel is applied on the skin overlying the structure to be examined.
- The sonographer then applies the transducer gently to the area, moving it as needed to obtain the images.
- After the exam is completed, the gel is removed.
- Most tests take approximately 30 min.

Posttest Care After Ultrasound Tests

- Most studies do not require specific posttest care.
- Patients having a transesophageal echocardiogram or a dobutamine stress echocardiogram will require monitoring for a short time after the study.
- All patients require information after a study is completed, including when results will be available and whom to call for information or to report side effects or complications.

Echocardiograms

Overview

- An echocardiogram (“echo”) is an ultrasound of the heart. In echocardiography, the high-frequency sound waves bounce off cardiac structures to provide information about the size, shape, and position of the heart, the thickness of the walls of the heart, and the function of heart valves, atria, and ventricles.
- **Doppler echocardiography** is performed with an echo to determine the direction and velocity of blood flow in the heart.
- There are several types of echocardiograms, which will be described in the following pages:
 1. Transthoracic Echocardiogram
 2. Transesophageal Echocardiogram (TEE)
 3. Dobutamine Stress Echocardiogram

New Technology: Echocardiogram Contrast

- The use of contrast in echocardiography is not new; however, new advancements in ultrasound techniques and contrast agents have improved the quality of contrast ultrasound studies.
- Obtaining good echocardiographic images is often difficult in the patient who is obese, has a barrel chest from COPD or other chest deformity, is in ICU, or is on a respirator. These technically difficult studies can be enhanced with contrast.
- Ultrasound contrast is made of gas-filled microbubbles smaller than a red blood cell. The microbubbles are encapsulated in a shell of albumin, phospholipid, or other substance, which helps prevent them from being destroyed in the high-blood flow circulation. The bubbles improve the quality of the images.
- Ultrasound contrast agents (USCA) travel into the right heart after IV injection, into the pulmonary circulation, and then into the left heart.
- Echocardiography with contrast is most commonly used for the evaluation of left ventricle function.
- The new contrast agents are generally well tolerated, but some patients may experience allergic reactions to contrast with albumin.

Transthoracic Echocardiogram

Ultrasound with or without contrast. **Informed consent generally not required. Potential complication: reaction to ultrasound contrast.**

PURPOSE

- Evaluate cardiac structures, function, and blood flow.
- Evaluate ejection fraction (EF), a measure of the heart's pumping ability (reference ranges: males: 63–77% females: 55–75%).
- Assess for thinning or thickening of heart walls and dilated atria or ventricles.
- Assess for abnormal wall motion or scar tissue.
- Assess for stenosed or leaking valves and valvular vegetations.
- Assess for atrial-septal defect, aortic dilation or dissection.
- Assess for pericardial effusion, thrombi, tumors, masses.

PROCEDURE

The patient wears a hospital gown and lies on the exam table. ECG leads are attached and the sonographer applies acoustic gel to the transducer and the patient's skin. The heart is assessed from several different views with the patient lying on his or her back or left side.

PRETEST PREPARATION

- See General Pretest Preparation in Tools Tab.
- There is no need to restrict food or fluids or withhold medication.
- Tell the patient the test is painless, without risk, and takes approximately 1 hour or up to 90 min if a Doppler Echo is performed.

POSTTEST CARE

- Echocardiography does not require any specific follow-up care.
- Tell the patient the test results will be available in 24–48 hr.

Transesophageal Echocardiogram (TEE)

Ultrasound using an internal transducer. Since the esophagus is closer to (lies behind) the heart, the TEE can provide better images.

Informed consent required. Potential complications: esophageal perforation or bleeding, complications from IV sedation.

PURPOSE

- Evaluate cardiac structures, function, and blood flow. May be done during surgery.
- Assess for thinning or thickening of heart walls, dilated atria or ventricles, abnormal wall motion, scar tissue, stenosed or leaking valves, valvular vegetations, atrial-septal defect, aortic dilation or dissection, pericardial effusion, thrombi, tumors, and masses.

PROCEDURE

The patient lies on his or her left side on the exam table. An IV is started and monitoring apparatus including ECG leads, blood pressure cuff, and pulse oximetry are placed on the patient. The patient receives IV sedation and the pharynx is sprayed with a local anesthetic.

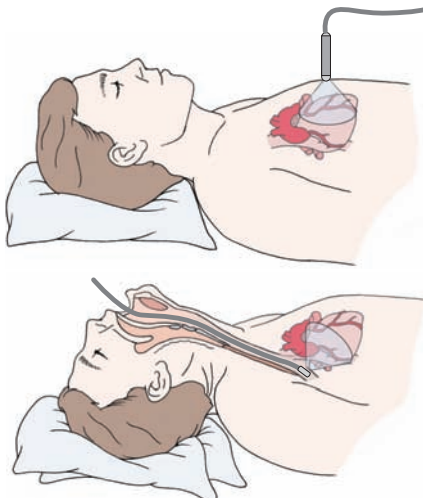
The flexible transducer probe is advanced into the pharynx and into the esophagus. The patient assists placement by swallowing. The transducer surface is manipulated into position by the external controls and the heart is studied from various angles. Ultrasound contrast (USCA) may be administered to improve image quality. The transducer is removed once all images have been obtained.

PRETEST PREPARATION

- The patient should not eat or drink anything after midnight the night before the test.
- Medications may be taken with a small sip of water.
- Because the patient will be NPO, oral hypoglycemic agents and insulins should be held until after the test. Consult with primary care physician.
- Tell the patient that his or her dentures will have to be removed.
- Tell the patient the test lasts approximately 45 min, but to be prepared to spend approximately 2 hr in the exam area.

POSTTEST CARE

- After the procedure, the patient will remain in the procedure room until he or she is fully awake and alert.
- The patient's blood pressure, respirations, and pulse will be monitored until stable.
- The patient cannot eat or drink for 2 hr after the test, and the gag reflex should be assessed before taking foods or fluids.
- Once the gag reflex has returned, the patient may eat soft foods but should avoid hot liquids for 24 hr.
- Patients discharged to home after the test must have another person available to drive them.



Transesophageal echocardiogram compared to transthoracic echocardiogram.

Dobutamine Stress Echocardiogram (DSE)

See *Transthoracic Echocardiogram* for description of the procedure. Dobutamine stress echocardiogram evaluates cardiac function before and after IV administration of dobutamine.

Informed consent required. Potential complications: dobutamine-induced side effects including hypertension, dysrhythmias, lightheadedness, chest pain, nausea, dyspnea.

- The test is ordered to evaluate coronary artery disease in patients unable to exercise on a treadmill. Dobutamine “stresses” the heart, increasing oxygen demand and therefore heart rate and blood pressure.
- The patient cannot smoke for at least 4 hr prior to test.
- The patient should not eat or drink anything except water 4 h prior to test. Coffee, tea, or carbonated or caffeinated beverages are not allowed.
- For the diabetic patient, the primary care physician and the cardiologist performing the study should be consulted regarding insulin/oral hypoglycemic medication adjustments; however, usually the insulin dose will be halved and the patient may have orange juice in the morning.
- The primary care physician or cardiologist performing the test should be consulted about withholding or adjusting beta-blockers before the test. Beta-blockers include atenolol (Tenormin), metoprolol (Lopressor, Toprol), nadolol (Corgard), and propranolol (Inderal). **👉 Check the patient’s medications including all natural and over-the-counter products and notify the echocardiographer for orders about withholding cardiac medications.**
- The patient will receive an IV and dobutamine will be administered during the echocardiogram.
- Patients may feel tachycardic, short of breath, or have a headache. The patient should report all physical sensations to the echocardiographer.
- After the study, the patient will remain in the testing area until any side effects subside.
- If the patient returns to a patient care floor, his or her vital signs should be monitored.

Vascular Ultrasound Studies (Doppler Ultrasound, Duplex Scan)

Overview

- Vascular ultrasound studies provide information about the structure and patency of blood vessels by combining standard ultrasound, which produces an image of the blood vessel, and Doppler ultrasound, which produces a graph or audible sound that reflects the velocity of blood flow through the blood vessel.
- The velocity of the blood can be used to determine if a blood vessel is occluded and the degree to which it is occluded.
- These studies are referred to as **Doppler Ultrasound** or **Duplex Scans**.
- **Continuous-wave (CW) Doppler (bedside Doppler)** refers to a hand-held device used to hear the blood flow in the extremities when pulses cannot be palpated. It is frequently performed at the bedside. Acoustic gel is applied over the presumed arterial site and the transducer is lightly applied to the area until blood flow is detected. **👉 Notify health care provider if pulses cannot be detected by Doppler.**
- **Color Doppler** is the application of color (red or blue) to standard ultrasound images of blood vessels to show the speed and direction of blood flow.
- **Power Doppler** is a technique that is more sensitive at detecting low blood flow than color Doppler and is used to evaluate blood flow through organs.
- The procedure for Duplex scans is similar to that of any ultrasound.
- The most common duplex scans involve the carotid arteries, the arteries of the legs, or the venous system of the legs.
- **Transcranial Doppler** and a duplex scan of the abdominal vessels are also done.

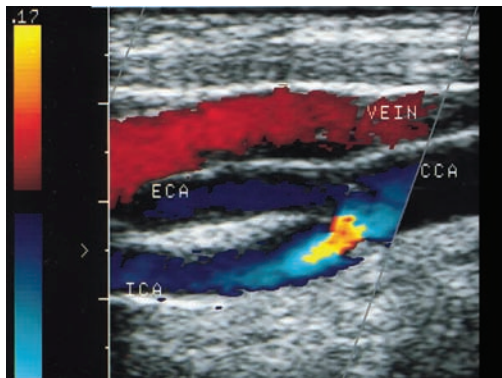
Carotid, Arterial, or Venous Duplex Scan

For all the following Doppler studies, refer to Pretest Preparation, Procedure, and Posttest Care for Ultrasound on page 139 and General Pretest Patient Education in Tools section.

Vascular Duplex Scans

Test Ordered	Indications/Comments
Carotid Duplex Scan	<ul style="list-style-type: none"> ◆ Plaque or stenosis, occlusion, aneurysm, and thrombus. ◆ May include assessment of major vertebral arteries. ◆ Provide quantitative measurements of the severity of stenosis.
Arterial Duplex Scan of Lower Extremities	<ul style="list-style-type: none"> ◆ Assessment of the femoral artery and its branches down into the calf. ◆ Plaque or stenosis, occlusion, aneurysm, arterial insufficiency, presence of collateral circulation, patency of graft site, and embolism. ◆ May include measurement of the ABI (ankle-brachial index). ABI is the ratio of the highest systolic pressure in the ankle vessel to the highest brachial systolic pressure. Used to predict the severity of peripheral arterial disease. A normal resting ABI is 1 or higher. ◆ May also be done on upper extremities
Venous Duplex Scan of Lower Extremities	<ul style="list-style-type: none"> ◆ DVT, thrombophlebitis, and venous insufficiency, ◆ Changes in venous blood flow characteristics before and after respiration are assessed to provide information about venous occlusion. Compression using gentle pressure is also used. ◆ Limitations of the study include: <ul style="list-style-type: none"> • Less accurate for detecting thrombi in the calf. • May not be able to distinguish between old and new clots. • Not helpful in diagnosing postoperative asymptomatic DVT.

Carotid Duplex Scan



US of carotid artery. Yellow area indicates blockage.

Other Ultrasound Studies

Bladder, Breast, Kidney, Liver/Biliary, Musculoskeletal, Obstetric, Pelvic, Prostate, Scrotal, and Thyroid Ultrasound Tests

For all the following ultrasound studies, refer to Pretest Preparation, Procedure, and Posttest Care for Ultrasound on page 139 and General Pretest Patient Education in Tools section.

Common Ultrasound Tests

Test Ordered	Indication/Comments
Bladder	<ul style="list-style-type: none"> ◆ Detect tumor; evaluate symptoms of UTI; assess bladder for residual urine. ◆ Must have a full bladder for study.
Breast	<ul style="list-style-type: none"> ◆ Evaluate abnormality detected by mammography; drainage of breast cysts and biopsy of breast masses. ◆ Not approved for breast cancer screening.
Kidney	<ul style="list-style-type: none"> ◆ Detect masses; differentiate between cyst and solid tumor; and aid in the diagnosis of kidney disease including infection, hydronephrosis, and renal calculi.
Liver/Biliary System (Abdominal US)	<ul style="list-style-type: none"> ◆ Evaluate abdominal pain, suspected gallstones, abdominal mass, enlarged spleen, abnormal liver function tests, or jaundice; assess for ascites, abdominal infection, and tumors. ◆ Patient may need to restrict food and fluid before test.
Musculoskeletal	<ul style="list-style-type: none"> ◆ Evaluate rotator cuff tear, shoulder pain, muscle tear, mass in soft tissues, tendonitis, or acute injury.

Test Ordered	Indication/Comments
Obstetric	<ul style="list-style-type: none"> ◆ Estimate fetal age; number of fetuses; evaluate abnormal bleeding, abnormal fetal heart beat, diabetes, follow-up for possible fetal abnormality.
Scrotal or Testicular	<ul style="list-style-type: none"> ◆ Evaluate testicular pain, mass, swelling, or trauma; infertility assessment.
Pelvic	<ul style="list-style-type: none"> ◆ Pelvic pain or mass; ectopic pregnancy, abnormal bleeding, screening for ovarian cancer; infertility work-up. ◆ Uses an intravaginal transducer.
Prostate	<ul style="list-style-type: none"> ◆ Follow-up to elevated PSA; assess prostate after abnormal rectal exam. ◆ Uses an transrectal (internal) transducer.
Thyroid	<ul style="list-style-type: none"> ◆ Assess mass or nodule; follow-up to abnormal thyroid blood tests, history of neck irradiation, or abnormality seen on other tests.

Overview of Nuclear Medicine Scans

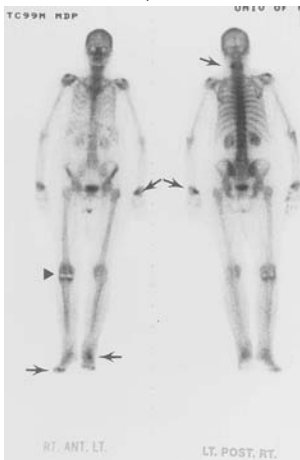
- In nuclear medicine scanning, a **radioactive isotope** (called a **radionuclide**, a **radiopharmaceutical**, or a **tracer**) is introduced into the body orally, by inhalation, or intravenously.
- The isotope travels through the bloodstream and accumulates (called “uptake”) to varying degrees in different tissues. The radionuclide then begins to decay, emitting radiation that can be detected with a gamma camera.
- The gamma camera contains a detector called a scintillation crystal. It scans the area of interest detecting the signals emitted by the radiation.
- The radiation signals are converted into light, the light is converted into an electric signal, and the electric signal is digitized. The computer can then provide an image of body structure and function that can be viewed on a monitor and manipulated.

How Nuclear Scans Show Disease

- A nuclear scan reveals disease because the degree to which tissues take up radiation reflects the metabolic activity of that tissue. Hypofunctioning tissue takes up less radionuclide than normal tissue and hyperfunctioning tissue, like cancers, takes up more.
- In normal tissues, the radionuclide is evenly distributed and shows up as uniformly gray. In abnormal tissues, the radionuclide shows up as either bright white— a “hot spot” indicating hyperfunction, or dark—a “cold spot” indicating hypofunction.
- The nuclear medicine image can be colorized to clearly show functional activity.
- Nuclear medicine body structure images are not as detailed as those obtained with magnetic resonance (MR) or computed tomography (CT), but the functional information obtained through nuclear scanning is very helpful in detecting disease.

Safety Issues with Nuclear Scans

- Nuclear medicine studies involve exposure to considerably lower doses of radiation than conventional x-rays or CT scans.
- Patients should be told to drink several glasses of water after nuclear scans to help excrete the radioactive isotope. All of the isotope will be excreted within a few days.
- Tell the patient that the isotope is only weakly radioactive and that their exposure does not represent a risk to themselves or family members.
- Inform the patient that the radiation dose for a nuclear scan is much less than the dose received when undergoing radiation treatment.
- Pregnant or nursing women should not have nuclear scans.
- Allergic reaction to the radioisotope is rare.



Whole skeleton bone scan. Diagnosis for this patient was degenerative joint disease in multiple sites (see arrows indicating increased uptake in the cervical spine, wrist, ankle, and toes). The arrowhead indicates a total joint prosthesis at the knee.

Nuclear Medicine Imaging Techniques

- **SPECT** (single photon emission computed tomography) acquires multiple views using a rotating gamma camera. It provides 3-D computer-reconstructed images of function.
- **PET** (positron emission tomography) is the most sensitive technique for imaging metabolic and biochemical pathways.
 - ◆ Biochemical activity in diseased tissues and cells changes before structure changes; therefore PET scanning can reveal disease in its very early stages.
 - ◆ Using different types of radionuclides and two opposing detectors, PET provides 3-D computer-reconstructed images of physiology and function. Radio tracers used for clinical PET imaging include:
 - ◆ O-15-labeled water, used to measure blood flow in the periphery.
 - ◆ N-13-labeled ammonia, used to measure blood flow in the heart.
 - ◆ FDG, a radioisotope-labeled glucose molecule, used to measure metabolic processes throughout the body. For example, the brain uses glucose for energy. By tagging a glucose molecule with a radioactive tracer and then scanning the patient's brain, PET can identify abnormal areas of the brain by revealing areas that are underutilizing glucose.
 - ◆ Many other tracers are under development.
- **FDG-PET** is gaining wide use in the diagnosis, staging, and treatment planning of many cancers. The higher rate of glucose metabolism in cancer cells makes cancer cells appear as hot spots in PET images. Because extremely minute amounts of FDG can be detected, FDG-PET scans are capable of detecting cancers long before anatomic changes are apparent.
- **FDG-PET** has applications in cardiology, neuropsychiatry, and other disease processes as well.
- **Dual-Modality PET/CT** imaging combines both PET and CT scanning in one device, merging the incomparable molecular imaging of PET with the detailed anatomic images of CT. PET/CT will dramatically change diagnosing, staging, treatment, and restaging of cancer patients. In addition to the improved diagnostic capability, PET/CT has the advantage of decreasing overall scanning times for cancer patients who typically undergo multiple scans throughout the course of their disease.

Bone Scan (Whole Body Bone Scan)

Nuclear scan to detect abnormal bone. Can show bone changes earlier than conventional x-ray.

PURPOSE

- Assess patients with unexplained bone pain.
- Assess for infection, tumor, bone metastasis, and fracture.
- Assess for conditions such as Paget's disease, tuberculosis, renal osteodystrophy, bone infarction, etc.

PROCEDURE

The patient receives an IV injection of the radioactive isotope (tracer). It takes 2–4 hr for the tracer to circulate and be absorbed by the bones, so the patient must wait until the correct time to scan. The patient is asked to drink water during this time to help excrete any unabsorbed isotope.

For scanning, the patient lies on the imaging table and the gamma camera passes over the body taking images. The entire body or a specific area can be scanned.

In a **3-phase bone scan**, a series of images is taken at different times—first immediately after the tracer is injected to assess blood supply, 10 min after the tracer is injected, and again in 2–4 hr to assess osteoblastic activity.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Inform the patient about the time it takes for scanning.

POSTTEST CARE

- There is no specific posttest care.

Brain PET (Positron Emission Tomography of the Brain, FDG Brain Scan)

PET (positron emission tomography) is a nuclear scan that shows biochemical function and activity. In brain PET, fluorine-18–labeled fluorodeoxyglucose (FDG), a radioactive version of glucose, is administered and disperses in the brain. The brain uses glucose as its main energy source; however, normal and abnormal cells absorb FDG differently.

PURPOSE

- Assess brain tumors and masses; assess effectiveness of chemotherapy; and distinguish benign from malignant tumors. Assess for tumor recurrence versus scar tissue.
- Assess brain injury.
- Localize the site of seizure activity.
- Diagnose Alzheimer's disease and other dementias.
- Evaluate psychiatric disorders such as schizophrenia or autism.
- Evaluate movement disorders such as Parkinson's disease.
- Map the areas of the brain to help guide surgery.

PROCEDURE

The patient has an IV started and the radioactive tracer (FDG) is administered. Uptake time for the PET brain scan is about 30 min; during which time the patient lies quietly in a dimly lit room. Once scanning begins, the table moves the patient to different positions in the scanner so that distribution of the tracer can be accurately determined. Scanning time is approximately 20 min.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- The patient should be NPO for 4 hr before testing.
- Medications can be taken with a small amount of water.
- Diabetic patients should have a blood glucose level between 100 and 200 mg/dL as elevated glucose levels can interfere with the test.

POSTTEST CARE

- There is no specific posttest care.

Brain SPECT Scan (Brain Perfusion Study)

Reveals cerebral blood flow and provides a 3-D image of the brain. Does not show the anatomy of the blood vessels like angiography but shows the pattern of perfusion throughout the brain. Damaged brain tissue shuts down its own blood supply; therefore, areas of the brain with vascular defects (decreased perfusion) indicate brain damage. Certain patterns of decreased perfusion are considered classic findings associated with specific diseases; for example, Alzheimer's disease, in which brain SPECT typically finds bilateral hypoperfusion of the temporal and parietal lobes with or without involvement of frontal lobes. ***Informed consent required.***

PURPOSE

- Diagnose Alzheimer's disease and other forms of dementia.
- Locate seizure foci.
- Evaluate cerebral ischemia and stroke patients.
- Evaluate brain injury.
- Evaluate patients with psychiatric and mood disorders.
- Detect recurrent brain tumor.
- Diagnose brain death.

PROCEDURE

The patient lies on the scanning table and the gamma camera is positioned around the patient's head. The technologist then administers the radioactive tracer intravenously. The camera immediately begins imaging the brain as the radioisotope (the tracer) travels into the cerebral circulation. After a waiting period of 30 min, the patient is repositioned under the camera and pictures are taken again.

To locate seizure foci: Requires two SPECT scans, one to show blood flow during a seizure and one to show blood flow without seizure activity. These will be done on two different days.

To evaluate cerebrovascular disease: Requires two SPECT scans, one to show the patient's baseline cerebral blood flow and one to show blood flow after administration of acetazolamide (Diamox). Acetazolamide dilates blood vessels and markedly increases cerebral blood flow; however regions supplied by significantly stenosed blood vessels will not show an increase in perfusion.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Tell the patient nuclear scanning is not painful and that the test will take about 1 hr.

POSTTEST CARE

- No special posttest care is required.

Gallium Scan

Total body nuclear scan used to detect inflammation, which is an indicator of infection or tumor. Radioactive gallium accumulates in areas of inflammation, infection, and benign or malignant tumors. ***Informed consent required.***

PURPOSE

- Assess patients with fever of unknown origin and scan for occult abscess or infection.
- Evaluate bronchogenic cancer, lymphoma, liver tumors, and malignant melanoma.

PROCEDURE

The patient receives an IV injection of the radioactive isotope. Scanning may begin as early as 4–6 hr later; however, since it takes longer for gallium to be taken up by the tissues, scanning is usually performed at 24-, 48-, and 72-hr intervals. For scanning, the patient lies on the imaging table while the gamma camera moves over and around the body. Scanning takes 1 hr to 90 min.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Gallium accumulates in the large intestine before excretion; therefore a laxative the evening before and an enema 1 hr before scanning may be required to avoid interference with the results.

POSTTEST CARE

- There is no specific posttest care.

Gastric Emptying Scan

Nuclear scan to assess symptoms of delayed gastric emptying.

PURPOSE

- Assess for diabetic gastroparesis, pyloric stenosis, or ileus.

PROCEDURE

The patient ingests an egg sandwich and juice that have been “labeled” with a radionuclide. The emptying of the food from the stomach is then followed over 1–2 hr.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- The patient should be NPO for 4 hr before the test.
- Tell the patient nuclear scanning is not painful and that the test will take about 1 hr.

POSTTEST CARE

- No special posttest care is required.

Gastrointestinal Bleeding Scan (Abdominal or GI Scintigram, Tagged Red Blood Cell Scan)

Nuclear scan that uses the patient’s red blood cells and a radioisotope to identify the source of GI bleeding. Because the blood is tagged with a radioactive isotope, the gamma camera can detect the blood when it pools in the GI tract.

PURPOSE

- Localize the site of active gastrointestinal bleeding.
- Aids in endoscopic or surgical repair of bleeding since visually locating bleeding source can be quite difficult for the surgeon.
- May be done prior to angiography.

PROCEDURE

The patient has an IV started in the nuclear medicine department. The patient’s blood is “tagged” with a radioactive isotope, usually by mixing the isotope (technetium-99m) with a sample of the patient’s RBCs and then reinjecting it into the patient. The radionuclide remains in the circulation and will extravasate into the lumen of the bowel at the site of the GI bleeding.

Scanning is performed immediately, after a delay, or several times at intervals over the day.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Tell the patient nuclear scanning is not painful and that the test will take about 1 hr.
- Patients with a suspected GI bleed may be quite sick and unstable. Assess vital signs, obtain latest hemoglobin and hematocrit results, and observe for signs and symptoms of shock.
- Arrange for someone to accompany the patient to nuclear scanning if the patient is unstable.

POSTTEST CARE

- No special posttest care required.

Liver/Spleen Scan

Nuclear scan of the liver and spleen.

PURPOSE

- Detect abscess, cyst, benign tumor, cirrhosis, or hepatitis.
- Assess liver and spleen following abdominal trauma.
- Detect primary or metastatic tumor.

PROCEDURE

The patient has an IV started in the nuclear medicine department. The radioactive isotope is administered IV and is taken up by the liver and spleen within a few minutes. After 15 min, the images will be taken. SPECT scanning provides the best images.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Tell the patient nuclear scanning is not painful and that the test will take about 1 hr.

POSTTEST CARE

- No special posttest care is required.

Lung Scan (V/Q Scan, Ventilation and Perfusion Lung Scans)

Nuclear scans that assess pulmonary perfusion and ventilation. Each is a separate test but typically both are performed at the same time to evaluate the possibility of pulmonary embolism (PE). The results of the perfusion scan are compared to the results of the ventilation scan to estimate the probability of PE. **Informed consent required.**

PURPOSE

- Evaluate patients with signs and symptoms of PE.
- Assess pulmonary perfusion.
- Assess lung function; evaluate asthma, pneumonia, obstructive lung disease, cystic fibrosis, and other lung diseases.

PROCEDURE

Ventilation scan: The patient inhales the radioactive tracer through a face mask. The patient will have to hold his or her breath and assume different positions while the gamma camera images the lungs. In certain pathologic lung conditions, pneumonia and emphysema, for example, the radioactive gas will not be evenly distributed as diseased tissue or exudates obstruct the airways and impede ventilation. In PE, the airways are not obstructed and the ventilation scan is normal.

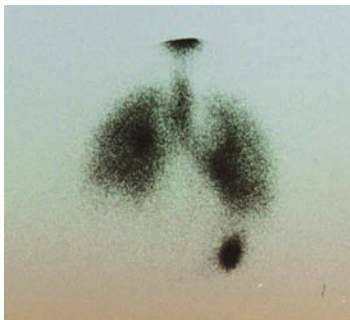
Perfusion scan: The patient lies on the imaging table and receives an IV injection of a radioactive tracer. The gamma camera scans the lungs to image the distribution of the tracer throughout the pulmonary blood supply. If the perfusion scan is abnormal, i.e., there are areas of the lungs not being perfused normally, it indicates obstruction of blood flow. If the areas of obstructed blood flow correlate with the areas of poor ventilation, it suggests lung disorders such as pneumonia or emphysema. If the ventilation scan is normal but the perfusion scan shows areas of obstructed blood flow, it suggests pulmonary embolism.

PRETEST PREPARATION

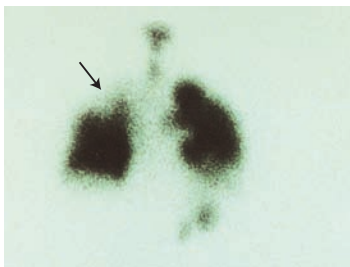
- See General Pretest Patient Education in Tools Tab.
- Explain the procedure to the patient; there are no special pretest preparations.

POSTTEST CARE

- There is no specific posttest care.
- Patients who require a lung scan are potentially unstable. Monitor the patient closely before and after the test. Implement interventions to improve respiratory status without delay.



Ventilation scan showing no filling defects



Perfusion scan of same patient showing defect in the RUL consistent with pulmonary embolism.

Multigated Blood Pool Imaging (MUGA Scan, Cardiac Blood Pool Scan, Ventriculogram, Radionuclide Angiogram [RNA]).

Nuclear scan that images the blood within the cardiac chambers and provides information about contractile (pumping) function of the myocardium. The study can be performed at rest and/or with exercise for comparison.

PURPOSE

- Assess effects of chemotherapy on cardiac muscle.
- Assess for weakened cardiac muscle, areas of previous myocardial infarction, and ventricular aneurysm.
- Determine ejection fraction (EF).

PROCEDURE

The patient lies on the table, has an IV started, and has ECG electrodes placed on the chest. Blood will be withdrawn so that it can be labeled with a radioisotope. After the blood is reinjected, the gamma camera will move over the patient's chest and begin imaging the heart.

The gamma camera is synchronized with the ECG to trigger imaging of the heart and blood flow at specific times during the cardiac cycle. Images of the heart in motion can then be viewed to determine whether the ventricle is contracting properly. The computer will analyze the amount of blood ejected from the ventricles to provide the ejection fraction (EF).

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- The patient should be NPO for 4 hr before the test.
- Tell the patient nuclear scanning is not painful and that the test will take 1–2 hr.

POSTTEST CARE

- No special posttest care is required.

Myocardial Perfusion Scan (Stress Thallium Scan, Sestamibi Scan, Treadmill-Mibi)

Nuclear SPECT scan that provides information about coronary blood flow, cardiac function, and ventricle size. The radionuclide used may be **thallium**, **tetrofosmin**, or **cardiolite**. Myocardial perfusion scans include:

- ◆ **Resting scan:** Performed at rest to detect areas of ischemic myocardium.
- ◆ **Exercise scan:** Performed with the patient exercising to assess for areas of ischemia.
- ◆ **Persantine, adenosine, or dobutamine scan:** Administered to patients who are unable to exercise. These drugs are vasodilators and will increase coronary artery blood flow without exercising.

Informed consent is required. Potential complications include dysrhythmias and myocardial ischemia. Contraindicated in acute myocardial infarction, unstable angina, uncontrolled cardiac arrhythmia, severe aortic stenosis, symptomatic heart failure, acute pulmonary embolus, myocarditis or pericarditis, or aortic dissection.

PURPOSE

- Evaluate chest pain, assess for coronary artery disease, evaluate collateral circulation, and assess graft patency.
- Evaluate myocardial infarction.

PROCEDURE

The patient has an IV started, electrodes placed on the chest, and a blood pressure monitor placed around the left arm.

For an exercise test: The patient begins exercising on a treadmill or exercise bike. The rate and incline of the treadmill or the resistance to pedaling are increased incrementally. The patient's heart rate, blood pressure, and perceived degree of exercise are monitored throughout. At the point of maximum exertion, the radionuclide is injected and the patient continues to exercise for another minute or two. The intensity of the exercise is decreased until the patient stops exercising. The patient is then escorted to the scanning room and placed supine on the table. The gamma camera rotates around the patient, taking multiple images. If an area of the heart is

ischemic, it will take up less of the radionuclide and will appear as a dark area, which is called a defect. After a waiting period, the patient is scanned again.

For a resting test: the patient does not exercise but lies on the scanning table. The radionuclide will be administered and, depending on which radionuclide is used, the gamma camera will begin scanning within 10–60 min.

For a persantine, adenosine, or dobutamine scan: A resting perfusion scan is usually performed first. Next, instead of exercising, the patient is given persantine, adenosine, or dobutamine IV over several minutes. 🖱️ **The patient may experience flushing, chest pressure, shortness of breath, dizziness, nausea, or headache during administration of the vasodilators.** 🖱️ **Adenosine and dipyridamole (Persantine) can cause hyperventilation and bronchospasm and should not be given to patients with asthma or bronchospasm. Dobutamine is contraindicated in patients with uncontrolled hypertension, unstable carotid artery disease, significant ventricular ectopy, and glaucoma.**

After the infusion is complete, the radionuclide is administered and the patient is scanned.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- Tell the patient not to eat or drink for 4 hr prior to the test.
- Beta blockers, ACE inhibitors, and calcium channel blockers may diminish test efficacy. 🖱️ **Check with physician about withholding these medications.**
- The patient should not drink caffeinated beverages for 24 hr before the test or take medications that contain theophylline for 48 hr before the test. Caffeine and theophylline interfere with and weaken the effects of adenosine and dipyridamole.
- Vital signs and ECG should be obtained before the test.

POSTTEST CARE

- No special posttest care is required. However, patients with known cardiac disease should be assessed for up to 24 hr after testing for signs and symptoms of cardiac ischemia.

Renogram and Renal Perfusion Scan (Furosemide Renal Scan, Captopril Renal Scan, Renal Scintigraphy)

Renal nuclear scans assess perfusion, structure, and function of the kidneys. They are the preferred diagnostic studies in children and patients with preexisting renal disease because exposure to iodinated contrast is avoided.

A **Captopril renal scan** is used to diagnose renal hypertension. In patients with renal artery stenosis, glomerular filtration is maintained by angiotensin. By administering captopril, an ACE inhibitor, this compensatory mechanism is temporarily removed and a transient decrease in the GFR will be seen.

A **furosemide renal scan** is used to increase output and observe for outflow obstruction.

PURPOSE

- Assess patients with acute or chronic renal failure.
- Aid in the diagnosis of renal artery stenosis, renal vein thrombosis, and renal artery embolism or infarction.
- Evaluate kidneys after trauma.
- Assess for infection such as renal abscess or nephritis.
- Evaluate chronic UTI.
- Assess transplanted kidney for acute or chronic rejection.

PROCEDURE

The patient has an IV started and the radioisotope is administered. The patient either sits or lies prone on the scanning table. Scanning occurs at various times, depending on which test is being performed. If the patient is having a furosemide test, the medication is administered IV. Captopril is given by mouth and scanning is done 1 hr later.

PRETEST PREPARATION

- See General Pretest Patient Education in Tools Tab.
- To enhance the accuracy of the results, the patient should be well hydrated before the study.
- The patient should void before the study.

POSTTEST CARE

- No special posttest care is required.

Other Nuclear Scans

The nuclear scans cited below are conducted similarly to other nuclear scans: The patient receives a radioactive isotope and is scanned by a gamma camera while lying on the scanning table. Generally, there is no pretest preparation; call the nuclear medicine department if in doubt. There is no specific posttest care, although some facilities suggest drinking plenty of fluids to help flush out the isotope.

Cardiac Scans

Test Name	Indications
FDG-Positron Emission Tomography (PET) Scan/ Myocardial Viability	<ul style="list-style-type: none"> ◆ PET scans give information about coronary artery blood flow. Also used to assess myocardial viability prior to revascularization procedures. ◆ Viable areas of the heart will have greater uptake of the radioisotope and appear as hot spots. Cold spots (darker areas with less uptake) indicate areas that are not viable.
First-pass Study (Cardiac Flow, Shunt Imaging)	<ul style="list-style-type: none"> ◆ Assess heart chamber disorders, especially septal defects. ◆ Radiopharmaceutical is injected and multiple images are taken as the tracer makes its "first pass" through the great vessels and chambers.
Infarct Avid PYP Scan (Myocardial Infarction Scan)	<ul style="list-style-type: none"> ◆ Used to evaluate chest pain, equivocal EKG changes, or increased CPK; assess for extension of MI, and rule out or diagnose acute myocardial infarction. Tc-99m PyP, the radioisotope, is taken up by necrotic myocardial cells. ◆ Timing of scan is very important; should be done within 48–72 hr after onset of symptoms.

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Endocrine Scans

Test Name	Indications
FDG-Positron Parathyroid	<ul style="list-style-type: none"> ◆ Detect and localize hyperfunctioning parathyroid adenomas.
Thyroid Scan	<ul style="list-style-type: none"> ◆ Determine thyroid size, function, and position and evaluate functional status of thyroid nodules. ◆ Evaluate of thyroid and neck masses. ◆ Evaluate of patients with history of head and neck irradiation. ◆ Quantitative thyroid uptake (I-131 uptake).

GI and Hepatobiliary Scans

Test Name	Indications
Hepatobiliary Scan (HIDA Scan, Cholescintigraphy)	<ul style="list-style-type: none"> ◆ Assess for acute or chronic cholecystitis, sphincter of Oddi spasm, biliary dyskinesia, and bile leak or obstruction. ◆ HIDA is the radioactive tracer that is injected IV, travels to the liver, and is excreted through the biliary system.
Hepatic Arterial Perfusion Scan	<ul style="list-style-type: none"> ◆ Assess for suspected liver metastasis. ◆ Frequently done simultaneously with CT portography.
Gastroesophageal Reflux Scan	<ul style="list-style-type: none"> ◆ Detect and quantitate reflux. ◆ Evaluate suspected aspiration pneumonia.
Meckels Scan (Gastric Mucosal Imaging)	<ul style="list-style-type: none"> ◆ Diagnose Meckle's diverticulum in the small bowel. ◆ Very sensitive and specific test.

(Continued on following page)

Test Name	Indications
Peritoneal Shunt Evaluation	<ul style="list-style-type: none"> ◆ Assess patency of peritoneal shunts. ◆ Requires injection of radionuclide into ascites fluid.
Schilling's Test	<ul style="list-style-type: none"> ◆ Evaluate cause of vitamin B₁₂ deficiency. Requires IM administration of vitamin B₁₂ and ingestion of radioactive tracer bound to vitamin B₁₂ followed by 24-hr urine collection. ◆ The radioactive B₁₂ should be excreted in the urine.
Tagged RBC Liver/Spleen Scan	<ul style="list-style-type: none"> ◆ Assess for hepatic hemangioma. ◆ Uses tagged red blood cells and SPECT
Urea Breath Test (UBT, <i>H. pylori</i> Breath Test)	<ul style="list-style-type: none"> ◆ Assess for <i>H. pylori</i> bacteria in the stomach. ◆ The patient provides a breath sample (breathes into a tube) after ingesting a capsule with trace amounts of a radioactive substance.
Tumor/Infection	
Octreotide Scan	<ul style="list-style-type: none"> ◆ Image, detect, follow-up, and monitoring of neuroendocrine tumors.
Oncoscint Scan	<ul style="list-style-type: none"> ◆ Detect recurrent colorectal and ovarian cancer.
Radionuclide Lymphangiogram	<ul style="list-style-type: none"> ◆ Evaluate lymph channels in patients with malignant melanoma or breast cancer.
White Blood Cell Scan	<ul style="list-style-type: none"> ◆ Evaluate patients with inflammatory bowel disease. ◆ Detect abscess or acute (<4–6 weeks) infection. ◆ Evaluate fever of unknown origin and assess for acute osteomyelitis or prosthesis or graft infection.

ARTHROSCOPY

- Visualization of a joint space, usually the knee or shoulder, with an arthroscope. The arthroscope is connected to a video camera and the joint is viewed on a monitor. If a procedure is planned, instruments are inserted through the arthroscope or through separate incisions. Removal of cartilage, repair of torn ligaments, and removal of inflamed or damaged lining (synovectomy) are a few of the procedures performed during arthroscopy.
- Arthroscopy is performed using general, spinal, or regional anesthesia. Preoperative and postoperative care are required. **Potential complications include infection and the risks of anesthesia.**

BIOPSIES

- Biopsy is the removal of tissue for microscopic examination.
- Types of biopsies include:
 - ◆ **Needle biopsy:** Includes fine needle and core needle biopsies. **Fine needle aspiration (FNA)** uses a thin needle and a syringe to withdraw a small amount of fluid and small pieces of tissue from the tumor. In a **core biopsy**, the needle is larger in diameter and removes a small cylinder of tissue. It is done using local anesthesia. If the tumor cannot be palpated, FNA or core biopsy can be done under fluoroscopic, ultrasonic, or CT guidance.
 - ◆ **Excisional or incisional biopsy:** Excisional biopsy involves removal of the entire tumor. Incisional biopsy involves removing a small piece of the tumor. Depending on the tumor location, excisional or incisional biopsy is done under local, regional, or general anesthesia.
 - ◆ **Endoscopic biopsy:** Involves removal of tissue during an endoscopic procedure of the gastrointestinal, genitourinary, or the respiratory tract.
 - ◆ **Laparoscopic and thoracoscopic biopsy:** Removal of tissue during laparoscopy, which is performed to view and obtain samples from the abdomen, or thoracoscopy, which is performed to view and remove samples from the chest. Both require a small incision.

BRONCHOSCOPY

- Direct visualization of the larynx, trachea, and bronchi with a bronchoscope. Used diagnostically for biopsy, aspiration of sputum for C&S and cytology, and direct examination of tissues and structures. Used therapeutically for removal of obstructing tissue, secretions, or foreign object.
- Bronchoscopy is performed using sedation and local anesthesia. Requires pre- and postprocedure care. **Potential complications include hypoxemia, aspiration, pneumothorax, and complications associated with anesthesia.** 🖐️ **Assess gag reflex after bronchoscopy and withhold all foods or fluids until patient is awake and alert and gag reflex has returned.**

CARDIAC CATHETERIZATION

- Catheterization of the right or left heart to visualize the coronary arteries, the great vessels, and the chambers of the heart.
- The catheter is inserted into the groin or arm and guided under fluoroscopy into the heart. The procedure involves taking blood pressure measurements within the heart's major arteries, sampling blood for oxygen content, coronary angiography, which requires use of an iodinated contrast, and a left ventriculogram, which also requires contrast and provides information about coronary blood flow.
- Pre- and postprocedure care are required. **Complications include stroke, reaction to contrast, perforation of blood vessels, heart attack, air embolism, dysrhythmias, thrombosis, and death.**

COLONOSCOPY

- Direct visualization of the colon from the anus to the cecum using a colonoscope. Used to identify causes of lower GI bleeding, screen for colon cancer, assess patients with ulcerative colitis, remove polyps, and biopsy suspicious tissue.
- Patients receive conscious sedation for the procedure. Requires a thorough bowel prep. Requires pre- and postprocedure care. **Potential complications include perforated colon and the risks of conscious sedation.**

COLPOSCOPY

- Direct visualization of the cervix and vagina using a colposcope, which includes a magnifying lens to better examine suspicious tissue. Is performed after an abnormal Pap smear and to evaluate daughters of women who received diethylstilbestrol while pregnant.
- Does not require specific pre- or postprocedure care. If a biopsy is performed (**conization**), the patient may experience bleeding for several hours. The patient should refrain from intercourse for 1 wk.

CYSTOMETROGRAM (CMG)/ URODYNAMIC STUDIES

- Assessment of detrusor muscle (the bladder muscle) function to evaluate cause of incontinence or other bladder dysfunction.
- The patient is catheterized and sterile saline is instilled into the bladder. The patient is asked to report sensations of fullness and urge to void.
- The test evaluates sensation, bladder function, and pressures during filling. It also measures total bladder capacity, detrusor compliance, and the ability to empty the bladder normally. Uninhibited bladder contractions, abnormal bladder wall compliance, and stress incontinence are measured.
- Also includes **urine flowmetry**, in which the patient voids into a special commode. Urine flow rate is then measured, which, when low, suggests diminished bladder contractility or outlet obstruction. High flow rates suggest poor urethral function, high voiding pressures, or a combination of both.

ELECTROENCEPHALOGRAM (EEG)

- Study that measures the brain's electric activity. Electrodes placed on the scalp transmit the signals of electric activity to the EEG machine, which records the amplitudes on graph paper.
- Used to evaluate seizure disorders, identify brain abscesses and tumors, evaluate head injuries, monitor cerebral blood flow during surgeries that affect cerebral blood flow (carotid endarterectomy), and establish brain death.

ELECTROMYOGRAM (EMG)

- Study that measures the electric activity of skeletal muscles at rest, during voluntary contraction, and with electric stimulation.

ELECTROPHYSIOLOGY STUDY (EPS)

- Electric “mapping” of defects in the heart’s conduction system. A catheter with multiple electrodes in its tip is threaded under fluoroscopy into the right heart via a peripheral vein. The location of sites responsible for dysrhythmias can be identified by pacing the heart and then inducing dysrhythmias. Radiofrequency waves can be used to obliterate the sites.
- Requires pre- and postprocedure care. **Potential complications include stroke, hemorrhage, ventricular tachycardia or fibrillation, and myocardial perforation.**

ENDOSCOPIC RETROGRADE CHOLANGIOPANCREATOGRAPHY (ERCP)

- ERCP combines x-rays and endoscopy to visualize the biliary pancreatic ducts. Used primarily to diagnose and treat gallstones, strictures, tumors, or cysts.
- A flexible fiberoptic endoscope is inserted into the esophagus, through the stomach, and into the descending duodenum.
- A catheter is inserted through the endoscope into the common bile duct.
- After the catheter is in place, contrast is injected into the biliary ducts and pancreas.
- Release of strictures, removal of obstruction, and tissue samples (biopsy) may be taken during the procedure.
- Pre- and postprocedure care are required. **Potential complications include pancreatitis, infection, bleeding, and duodenal perforation.**

ESOPHAGEAL FUNCTION STUDIES

- Manometric tests that measure the pressure of the lower esophageal sphincter and esophageal motility. Performed by passing a pressure-sensitive catheter into the esophagus and slowly withdrawing it.
- Esophageal function studies include pH monitoring, esophageal acidity assessment, and an acid-perfusion test, which helps to distinguish esophageal pain from cardiac pain.

ESOPHAGOGASTRODUODENOSCOPY (EGD)

- Endoscopic examination of the esophagus, stomach, and duodenum. EGD is both diagnostic and therapeutic. Interventions possible during EGD include coagulation of bleeding vessels, biopsy, dilatation of strictures, stent placement (in the biliary system), and gastrostomy.
- Pre- and postprocedure care are required. **Potential complications include perforation, aspiration, or complications associated with conscious sedation.**

EVOKED POTENTIAL STUDIES (EP STUDIES)

- Studies that measure electric signals along nerve pathways. Used in the diagnosis of demyelinating diseases, stroke, spinal cord injury, hearing loss, Parkinson's disease, peripheral nerve damage, and other conditions in which nerve damage is a feature.
- Neural activity is evoked by visual stimulation, auditory stimulation, or somatosensory stimulation (mild electric shock).

FETAL MONITORING

- Cardiac monitoring of the fetus for indicators of stress. Types of monitoring include:
 - ◆ **External Fetal Monitoring:** Electrodes that sense fetal heart rate and contractions are placed on the abdomen. Assess how well the fetus is tolerating contractions.
 - ◆ **Nonstress Test (NST):** Measures the FHR accelerations with normal (fetal) movement. FHR should accelerate by 15 bpm during a 20-min interval. If the baby does not move during the initial testing time, massaging the abdomen or using a loud noise to stimulate fetal movement may be done.
 - ◆ **Contraction Stress Test (CST):** Contractions are induced either by nipple stimulation (**nipple stimulation test**) or oxytocin (**oxytocin challenge test [OCT]**). The FHR should not show late deceleration during contractions, which may indicate hypoxia.
 - ◆ **Internal Fetal Monitoring:** Involves placing an electrode directly on the fetal scalp through the cervix. Performed if external monitoring is not working reliably. The electrode is placed transvaginally. The wire is strapped to the mother's thigh and attached to a monitor.

HOLTER MONITOR

- Ambulatory ECG monitoring in which the patient has continuous ECG monitoring for 24 hr. The patient has ECG leads placed on his or her chest. The leads are attached to the Holter monitor, which is a small battery-operated recorder. The patient keeps a diary for 24 hr noting symptoms and engaging the event marker on the monitor when he or she experiences cardiac symptoms. The recordings are later reviewed by a cardiologist.
- Holter monitoring is used to identify transient dysrhythmias.

OXIMETRY

- Noninvasive method of monitoring the percentage of hemoglobin (Hb) that is saturated with oxygen. The pulse oximeter is a probe linked to a computer. The probe is placed on the patient's finger or ear lobe. The oximetry unit displays the percentage of Hb saturated with oxygen.
- Values under 90% indicate severe hypoxemia.

PULMONARY FUNCTION TESTS

- Assessment of the functional status of the lungs using a spirometer connected to a recorder. Used in the work-up of patients with respiratory symptoms, to quantitate degree of respiratory impairment, to assess pulmonary status before surgery, and in the ongoing assessment of patients with known pulmonary disease.
- Basic functional status is determined by measuring:
 - ◆ The amount of air that can be moved in and out of the lungs.
 - ◆ How quickly the air is moved in and out.
- **Spirometry with flow volume loops** measures expiratory volumes and flow rates. In a sitting position with nose clips on, the patient breathes into a mouthpiece making a maximal inspiratory and expiratory effort. Flow volume loop is a method that graphically illustrates the patient's inspiration and expiration. While the patient uses the spirometer, the flow rate is digitized and plotted against the volumes. The result is a graph showing a continuous loop from inspiration to expiration. The shape of the flow volume loop is important in interpreting results.

- PFTs are taken again after administration of a bronchodilator to determine if there is improvement in the expired volumes and flow rates. They are also repeated after inhalation of methacholine to induce bronchial hyperreactivity. Asthmatic patients will demonstrate hyperreactivity at much lower doses.
- Spirometry results are reported in absolute values and as a predicted percentage of normal. However, normal values vary depending on gender, race, age, and height. Also, reference ranges vary with the laboratory. Reference formulas must be applicable to the patient population being tested.
- Many specialized PFTs acquire other types of information; however, basic spirometric tests still provide considerable detail and include:

Basic Pulmonary Function Tests

Test	Description
FVC —Forced Vital Capacity	After taking the deepest breath possible, the FVC is the volume of air that can be forcibly and maximally exhaled until no more can be expired.
FEV1 —Forced Expiratory Volume in 1 Sec	The volume of air that can be forcibly exhaled from the lungs in the first second of a forced expiration.
FEV1/FVC —the ratio of FEV1 to FVC (also called %FEV1)	Indicates the percentage of the total FVC exhaled during the first second of forced exhalation.
FRC —Functional Residual Capacity	The amount of air left in the lungs after normal expiration.
RV —Residual Volume	The amount of air left in the lungs after maximal expiration.
TLC —Total Lung Capacity	The total amount of air in the lungs at maximal inspiration
PEFR —Peak Expiratory Flow Rate	The maximum exhaled flow rate.

TILT TABLE TEST

- Performed to evaluate vasovagal or neurocardiogenic syncope (fainting), which occurs when heart rate slows and blood pressure decreases secondary to an abnormal reflex of the nervous system that causes blood vessels to dilate.
- The patient has an IV started, has continuous ECG and blood pressure monitoring, and is secured to the table. The table is tilted to 60–80 degrees for 45 min. If the patient does not faint, isoproterenol is administered; the patient is then tilted again for another 45 min. If the patient does not faint, the test is considered negative. If the patient faints, the tilt table will be laid flat and the patient will be monitored. Usually recovery is immediate.

TRIPLE SCREEN TEST

- Blood test for pregnant women that checks the levels of hCG (human chorionic gonadotropin) and estriol, which are produced by the placenta, and the level of alpha-fetoprotein (AFP), which is produced by the fetus.
- The purpose is to identify babies at increased risk for chromosomal defects such as Down's syndrome or birth defects such as neural tube defects.

General Pretest Preparation

All patients undergoing diagnostic testing have similar needs for information, explanation, and instruction. Instructions should be provided orally and in writing and in language the patient can understand (no medical jargon). At the time the test is ordered, tell the patient:

- The name of the test, why it's done, and how it will help with the patient's health problem.
- How the test is done and what the patient will feel during the test.
- How to prepare for the test.
- Risks associated with the test.
- Factors that will affect the test, such as not following pretest preparations, moving during the test, interfering medications, timing of the test, etc.
- When test results will be available and who will inform the patient of the results.
- How to schedule the appointment for the testing and where to go for the testing.

In addition to providing factual information, always bear in mind that patients about to undergo diagnostic testing may be anxious about the test and anxious about the potential results. Ask and discuss with the patient:

- What fears or concerns he or she has regarding the test including:
 - ◆ Fear of pain.
 - ◆ Fear of test results that indicate illness.
 - ◆ Implications of the results; i.e., the next step—possible treatment plans, need for further testing, medications, etc.
- Do not minimize the patient's concerns. Testing and the possibility of illness are extremely stressful.

At the time of the test, the technician or radiology staff person will perform a focused assessment, which varies according to the test. Patients undergoing invasive testing or testing with iodinated contrast need to have a focused assessment before the test including assessment of vital signs, pertinent blood tests, medical history, and history of allergic or other reaction to contrast.

Venipuncture Procedure

IDENTIFY THE PATIENT

- Check the patient's wrist band against the order sheet or lab requisition; make sure the patient's name and hospital number are legible.
- **Check if the patient is on anticoagulants or has a history of bleeding disorders. Special care must be taken to achieve hemostasis.**

OBTAIN AND PREPARE EQUIPMENT

- Gloves
- Labels
- Tourniquet
- 2 × 2 gauze pad
- Alcohol sponge
- Adhesive strip
- Sharps container
- 21- or 22-gauge *safety-engineered* needle, safety needle holder
- Appropriate color evacuated collection tubes. (See Tube Top Colors, pp. 183-184.)

SELECT VENIPUNCTURE METHOD

- **Evacuated tube system:** Evacuated tubes have color-coded tops and fill by vacuum. The tube is used with a collection tube holder and a safety needle to collect blood directly into the tube. The collection tube holder helps in handling the needle and collection tube and allows for changing tubes to obtain multiple samples with one "stick." When the collection tube is disengaged from the needle, a small rubber sleeve covers the needle and prevents loss of blood while the tube is changed.
- **Syringe method:** Uses a 10-mL syringe and a needle to puncture the vein and aspirate blood. The needle is then inserted into the colored tube top for transportation to the lab.
- **Butterfly method:** Uses a small butterfly needle and a syringe to obtain the venous sample.

SELECT THE SITE

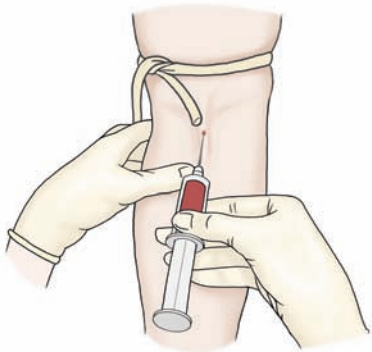
- Place the patient in a supine or semi-Fowler's position with ventral surfaces of both arms up.
 - Examine both arms for suitability. **✘ Never draw blood from the arm if it is on the side of a mastectomy, is edematous, has an IV below the venipuncture site, has a vascular access or fistula, or has a hematoma.**
 - Tie a tourniquet approximately 4 inches above the intended venipuncture site. Be sure that it is tight but not uncomfortable.
 - Ask the patient to make a fist.
 - Assess the antecubital area of the arm. The basilic, cephalic, and median cubital veins are all usually near the skin surface.
 - Palpate the vein. It should rebound (bounce).
 - If the antecubital veins of both arms are not suitable, assess the forearms first and then the hands and wrist.
- ✘ If a suitable vein cannot be found, DO NOT ATTEMPT BLOOD DRAW. Remove the tourniquet and inform the nurse in charge or call the physician.**

PREPARE THE SITE

- Observe Standard Precautions.
- Don gloves.
- Open an alcohol pad and rub the site in concentric circles, working outward from the center. To avoid patient discomfort, allow the area to air dry for 30–60 sec (or wipe with a sterile, dry gauze pad).
- Povidone-iodine preps may be used. Check if patient is allergic.

PERFORM THE VENIPUNCTURE

- With your nondominant hand, stabilize the vein by holding the vein between the index finger and thumb.
- With your dominant hand grasp the collection tube holder and turn so that the bevel is UP. Holding the needle at a 15-degree angle, enter the skin directly above the vein and in the same direction as the blood flow. Advance needle into vein. Entry should be smooth and quick.
- See Other Venipuncture Methods on page 181 for procedures for obtaining blood with a syringe using a butterfly or a needle.



Venipuncture technique. The thumb of the left hand stabilizes the vein.

ENGAGE EVACUATED COLLECTION TUBE

- Ease the collection tube further into the safety needle holder.
- Remove the tube when it is filled.
- If the tube contains an additive, gently invert the tube 8–10 times to mix the additive with the blood.
- Engage subsequent collection tubes as needed.
- Obtain specimens in the following order:
 - ◆ sterile blood culture tubes
 - ◆ nonadditive clotting tubes (red)
 - ◆ coagulation tubes and tubes containing citrate (blue)
 - ◆ serum-separator tubes (speckled)
 - ◆ tubes containing heparin (green)
 - ◆ tubes containing EDTA (lavender, royal blue)
 - ◆ tubes containing acid citrate dextrose (yellow)
 - ◆ tubes containing sodium fluoride and potassium oxalate (gray)

REMOVE NEEDLE

- Release tourniquet as last tube is filling and disengage the collection tube from the safety needle.
- Apply a 2 × 2 gauze pad over the site and withdraw needle.
- Apply direct pressure with 2 × 2 dressing.

CONTROL BLEEDING

- Raise the arm above the heart level for approximately 3–5 min to control bleeding, if necessary. Hold gauze in place until bleeding has completely stopped.
- Fold a single 2 × 2 inch gauze pad into quarters and tape it tightly to the site.

DISCARD USED NEEDLES SAFELY

- **DO NOT RECAP, cut, or bend needles. If recapping is done, use approved “One-Handed Method” or recapping block. NEVER RECAP WITH TWO HANDS.**
- **Do not separate needle from the blood tube holder. Dispose of the entire unit in the proper puncture-resistant SHARPS container.**

LABEL SPECIMENS AT THE BEDSIDE

- Send to the lab with a properly filled out requisition.

Other Venipuncture Methods

Venipuncture Using a Syringe

- Use a syringe when the patient's veins are small or fragile because suction from an evacuated tube can cause the vein to collapse. Using a syringe allows control of the amount of suction.
- Steps for entry into the the vein are the same as with the evacuated tube system.
- Once in the vein, pull back on plunger to obtain desired amount of blood. Release tourniquet and withdraw needle while applying a folded gauze 2×2 and pressure to venipuncture site.
- Transfer blood to appropriate tubes by first replacing needle with large-bore (18 gauge) needle (prevents hemolysis).
- Insert needle into the stopper and allow tube to fill by vacuum.
- Follow the correct order of tube top color.

Venipuncture Using an IV Infusion Set (Butterfly)

- Used for venipuncture from a very small or fragile vein.
- For small children use a 23-gauge butterfly IV infusion set attached to a 1- or 3-mL syringe (prevents excessive suction).
- Steps for entry into the the vein are the same as with the evacuated tube system.
- Grasp the wings between thumb and index finger, hold skin and vein taut with other hand, and penetrate the skin with the needle.
- As soon blood is visible in the tube, pull back on the plunger or engage the vacuum tube. Release the tourniquet, remove the needle, and complete the procedure.

Skin Puncture

- Blood for laboratory analysis is sometimes obtained by skin puncture rather than venipuncture.
- Sites for skin puncture include the finger, heel (in infants), or ear lobe. To perform skin puncture:
 - ◆ Select the site.
 - ◆ Apply a warm compress to the site to increase blood flow.
 - ◆ Clean the area with 70% alcohol.
 - ◆ Thoroughly dry the site with a gauze sponge.













- ◆ Firmly prick the site with a lancet.
- ◆ To avoid diluting the blood sample with tissue fluid, wipe away this first drop of blood and do not squeeze or milk the surrounding tissue.
- ◆ Collect the blood in a capillary tube, on a slide, onto a test strip, or into a small container.
- ◆ If using a capillary tube, hold it horizontally and touch the end of the tube to the drop of blood without touching the skin. The tube will fill by capillary action.

Hemolysis

- Hemolysis is the destruction of the encasing membrane of the red blood cell and the subsequent release of hemoglobin into the plasma.
- Hemolyzed blood specimens can give false values and therefore are not acceptable for testing.
- Hemolyzed specimens are often the result of incorrect venipuncture technique or mishandling of the specimen.
- Tips to avoid rejected specimens include:
 - ◆ Use a 20- to 22-gauge needle.
 - ◆ If air leaks from around the needle or loss of vacuum occurs, replace the tube and collect a new specimen.
 - ◆ *Do not remove the needle from the vein with the evacuated tube still engaged in the safety needle.* This will cause air to enter the tube, which can damage red blood cells.
 - ◆ When using a syringe to withdraw blood, pull back on the plunger gently and evenly to avoid damaging cells.
 - ◆ Allow venipuncture site to dry after cleaning. Alcohol used can contribute to hemolysis.
 - ◆ Do not collect a specimen from an area of the arm that has a hematoma.
 - ◆ Consider discarding specimens if the blood enters the tube too slowly or if accessing the vein was difficult. Both these scenarios often result in damage to the red blood cells and hemolysis. If good blood flow is established, collect another sample from the same site and discard the first sample. If good blood flow cannot be established, select a new venipuncture site.

Tube Top Colors: Additives and Uses

Common Blood Collection

Color (Additive)		Color (Additive)	
Red (None)		Yellow (SPS-Sodium Polyanetholesulfonate)	
Red Marble Top or Gold (Clot activator and gel for serum separation)		Yellow Marble Top or Orange Thrombin	
Light Blue (Sodium Citrate)		Light Green Lithium heparin and gel for plasma separation	
Green (Sodium Heparin or Lithium Heparin)		Pink (EDTA)	
Lavender (EDTA ethylenediamine teraacetic acid)		Tan (Sodium Heparin (glass tubes) EDTA (plastic))	
Gray (Potassium Oxalate sodium Fluoride or sodium Fluoride)		Royal Blue (Sodium Heparin EDTA None)	

Tube Top Colors: Uses

Examples of Common Labs

Red:

Blood bank, type and cross, or used as a discard tube

Red Marble-top or Gold:

Chemistry, Ca, BUN, creatinine

Light Blue:

Coagulation studies, PT, PTT, INR, fibrinogen

Lavender:

Hematology, CBC, H&H platelet counts

Gray:

Chemistry, blood glucose

Green:

Chemistry ionized Ca

Urine Sample Collection

Random Urine Collection

- If time permits, collect the first voided specimen of the morning.
- Collect the specimen in a nonsterile container with a screw top lid.
- If the specimen cannot be sent to the lab immediately, refrigerate until taken to the lab.
- Specimens can be refrigerated for 24 hr. They should be received in the laboratory within 1 hr of removal from refrigeration.

Clean Catch Midstream Urine Collection

Female Patients

Tell the patient to:

- Wash her hands well, remove the lid from the collection cup, and open the towelette package.
- Separate the labia and keep the labia separated until the urine is collected.
- Cleanse the meatus with one towelette using a front to back wipe.
- Repeat with next towelette.
- Keep the labia separated and begin to urinate into the toilet.
- Move the collection cup into the urinary stream making sure the cup does not come in contact with clothing, legs, or genitals.
- Fill the container halfway, remove the cup from the urinary stream, and finish voiding into the toilet.
- Wash her hands, replace the lid on the container, and dry the outside of the container.

Male Patients

Tell the patient to:

- Wash his hands well, remove the lid from the collection cup, and open the towelette package.
- Pull back the foreskin, if present, to expose the urinary meatus.
- Wash the meatal opening with the towelette using a circular motion.
- Repeat with the remaining towelettes.
- Begin voiding into the toilet.

- Move the collection cup into the urinary stream making sure the cup does not come in contact with clothing, legs, or genitals.
- Fill the container halfway, remove the cup from the urinary stream, and finish voiding into the toilet.
- Wash his hands, replace the lid on the container, and dry the outside of the container.

Urine Collection from a Closed Urinary Drainage System

- Wash hands.
- Clamp the drainage tubing below the port.
- Obtain gloves, syringe, needle, alcohol wipe, and collection cup.
- Label collection container.
- Don gloves and clean the port with an alcohol swab.
- Insert the needle into port and aspirate at least 10 mL of urine.
- Transfer the urine from the syringe into the specimen cup.
- Unclamp the catheter.
- Discard needle in sharps container. Wash hands.
- Send the specimen to the lab

Timed Urine Specimen Collection (2-, 6-, 12-, or 24-Hr Urine)

- Urine samples collected over a specific period of time are called timed specimens.
- Times may be as short as 2 hr or as long as several days.
- At the start of the collection, have the patient void and discard this urine sample. This is the start time and should be noted on the time on the collection container. For 24-hr urines, this ideally would be the first void of the morning.
- Collect all urine from that point onward for the specified period of time. Unless instructed otherwise, keep the urine refrigerated or on ice in the bathroom.
- At the end of the time period, void and add this specimen to the container. Note the time of the last voided urine. *If collecting a 24-hr urine sample, the last urine collected should be voided at the exact same time as the first urine was discarded.*
- Once the collection time period is complete, send the urine to the lab immediately.
- Note that usual fluid intake is allowed during the urine collection period; however dietary restrictions may apply. (Check with lab.)

Respiratory Secretions Collection

Nasopharyngeal or oropharyngeal swabs or sputum specimens may be collected for viral and/or bacterial diagnostic testing.

Nasopharyngeal or Oropharyngeal Swabs

- **Nasopharyngeal swabs:** Insert a swab into the nostril parallel to the palate. Leave the swab in place for a few seconds to absorb secretions. Swab both nostrils.
- **Oropharyngeal swabs:** Swab the posterior pharynx and tonsillar areas, avoiding the tongue.
- If using a culturette swab, insert into plastic container and break the seal that releases the viral transport media. If culturette swabs are not available, place the swabs immediately into sterile vials containing 2 mL of viral transport media. Break the applicator sticks off near the tip to permit tightening of the cap.
- Label each specimen container and send to the lab.

Sputum Sample

- Explain to the patient the difference between sputum and oral secretions. Only a small amount of sputum is required, but it must be sputum and not saliva.
- Have the patient rinse his or her mouth with water (to help reduce contamination by normal oral flora).
- Tell the patient to take three or four deep breaths and cough lightly to help raise secretions from the bronchial tree.
- Next have the patient cough forcefully and directly into a sterile screw-cap sputum collection cup or sterile dry container.
- Label the specimen and send to the lab.
- If the patient is unable to raise a sputum sample, the sample may be obtained by the following means:
 - ◆ **Induced sputum:** must be ordered by physician, usually done by a respiratory therapist. Deep coughing is induced by irritation.
 - ◆ **Bronchial washings:** done by the physician during a bronchoscopy.

Normal Flora

Microbiology reports identify the disease-causing organisms from cultures. Many organisms are found in different body sites, but do not produce disease (unless there is an abnormally high amount). The microbiology report may say “normal flora” to mean that no disease-producing organism was found, or it may list all organisms found and not distinguish which are normal flora. The following list identifies organisms that normally live in and on the body.

SKIN FLORA

- Alpha hemolytic streptococci
- Coagulase-negative staphylococci
- *Bacillus* species
- *Corynebacteria* species

RESPIRATORY FLORA

- Alpha hemolytic streptococci (not *Enterococcus*)
- Nonhemolytic streptococci
- *Corynebacteria* species
- *Neisseria* species
- The following pathogens may be part of the routine flora if they do not predominate:
 - ◆ Coagulase-negative staphylococci
 - ◆ *Haemophilus influenzae*
 - ◆ *Haemophilus parainfluenzae*
 - ◆ *Moraxella catarrhalis*
 - ◆ *Neisseria meningitidis*
 - ◆ *Streptococcus pneumoniae*

GENITOURINARY TRACT FLORA

- Alpha hemolytic streptococci (not *Enterococcus*)
- Nonhemolytic streptococci
- Coagulase-negative staphylococci (if not predominating)
- *Corynebacteria* species
- Lactobacilli

Safety Issues When Collecting Specimens

The OSHA (Occupational Safety and Health Act) Bloodborne Pathogens Standard mandates that all laboratory specimens be treated as potentially infectious. Follow these guidelines to minimize exposure and spread of organisms:

- **☞ Wear gloves whenever there is potential for exposure to blood, body fluids, or tissue specimens.**
- **☞ Use goggles, gown, and mask in areas where contact with aerosols or large amounts of body fluids may occur (for example, in the OR, procedure room, or emergency department).**
- **☞ Do not recap or cut needles prior to disposal. Always discard needles in the proper needle-disposal containers. Do not remove safety needles from collection tube holders. Dispose of holder and needle.**
- **Wash hands frequently!**
- Tightly cap all specimen containers to prevent leakage or spills.
- Make sure specimen container is not leaking or cracked. If it is, place in another container before sending to lab.
- Before sending specimens to the lab, place collection container in a sealed bag labeled with a biohazard sticker.
- Make sure laboratory requisition forms are not contaminated. If they are, prepare new ones.
- Consider a hepatitis B virus vaccination. It is recommended for health care personnel in contact with patients and body fluids.

Physiologic Changes in Older Adults

Changes in Lab Values in Older Adults

Laboratory Values	Age-associated Change
Alkaline phosphatase	↑ up to 20% in men and up to 37% in women
Serum albumin	Slight ↓
Serum magnesium	↓ 15%
Uric acid	Slight ↑
Total cholesterol	↑ 30–40 mg/dL by age 55 in women and age 60 in men
HDL cholesterol	↑ 30% in men and ↑ 30% in women between ages 30 and 80
Triglycerides	↑ 30% in men and 50% in women between ages 30 and 80
Fasting blood glucose	↑ 2 mg/dL per decade after age 30
2-hr postprandial blood glucose	↑ up to 100 mg/dL plus age in years after age 40
PaO ₂	↓ 25% between ages 30 and 80
Creatinine clearance	↓ 10 mL/min/1.73 m ³ per decade
Leukocyte count	Slight ↓
ESR (erythrocyte sedimentation rate)	↑ (upper limit 40 mm/hr in men and 45 mm/hr in women)

Source: Brigden ML, Heathcote JC. (2000). Problems in interpreting laboratory tests. What do unexpected results mean? *Postgraduate Medicine* 107(7). http://www.postgradmed.com/issues/2000/06_00/brigden.htm. Accessed 9/22/04

Abbreviations Used in Lab Results

<	less than	L	liter
>	greater than	m	milli (10^{-3} or 0.001)
c	centi (10^{-2} or 0.01)	mEq	milliequivalent
CrCl	creatinine clearance	mg	milligram
d	deci (10^{-1} or 0.1)	mc or μ	micro (10^{-6} or 0.000001)
dL	deciliter	mmol	millimole
Eq	equivalents	mol	mole
f	femto (10^{-15} or 0.0000000000000001)	mOsm	milliosmoles
g or gm	gram	n	nano (10^{-9} or 0.000000001)
gm/dL	grams per deciliter	Osm	Osmoles
IU	International Unit	p	pico (10^{-12} or 0.000000000001)
k	kilo (10^3 or 1000)		

Reference Ranges Explained

- A reference range for any given test is the average of the results from a large population of healthy individuals plus or minus 2 standard deviations.
- Reference range rather than normal range is the preferred term.
- Many factors, including the reagents and equipment used by different labs, influence reference ranges and each lab must establish its own reference ranges.
- Only a few analytes (i.e., substances that are analyzed) have nationally standardized testing methods and report formats.
- Glucose, cholesterol, and prostate-specific antigen are three commonly performed tests that have been standardized.
- In most cases, the patient's result must be compared to the reference range supplied by the laboratory that ran the test for accurate interpretation.
- Labs also use different units of measure to report many test results.

Reusable Lab Test Results Forms

Blood Chemistry Screen/Metabolic Panel

Patient's Name:

	Date/Time	Date/Time
Albumin		
ALP (alkaline phosphatase)		
ALT (alanine aminotransferase)		
AST (also called SGOT)		
Bilirubin, total		
BUN (blood urea nitrogen)		
Calcium		
Chloride		
Creatinine		
Glucose		
Potassium		
Protein, total		
Sodium		

Hematology Panel

Patient's Name:

	Date/Time	Date/Time
RBC		
Hgb		
Hct		
MCV		
MCH		
MCHC		
RDW		
Platelets		
WBC		
Neutrophils, bands		
Neutrophils, segmented		
Lymphocytes		
Monocytes		
Eosinophils		
Basophils		

Cardiac Biomarkers

Patient's Name:

	Date/Time	Date/Time
CK (creatine phosphokinase)		
CK-MB		
Troponins (TnI/TnT)		
Myoglobin, serum		
ACB (albumin cobalt binding)*		
BNP (B-type natriuretic protein)		

*May be called IMA for ischemia-modified albumin.

Coagulation Profile

Patient's Name:

	Date/Time	Date/Time
PT/INR		
PTT		
Platelets		
D-dimer		
Fibrin split products		
Fibrinogen		

ABG Results

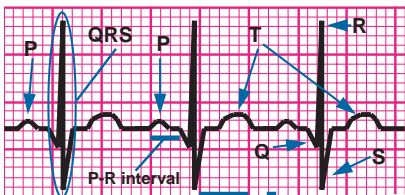
Patient's Name:

	Date/Time	Date/Time
pH (7.35–7.45)		
PaO ₂ (80–100 mm Hg)		
PaCO ₂ (35–45 mm Hg)		
O ₂ Saturation (95–100%)		
HCO ₃ (21–28 mEq/L)		
Base Excess (–2 to +2 mEq/L)		

Quick ABG Interpretation

	pH	HCO ₃	PaCO ₂
Respiratory acidosis	↓	↑ or normal	↑
Compensated	normal or slightly ↓	↑	↑
Respiratory alkalosis	↑	↓ or normal	↓
Compensated	normal or slightly ↓	↑	↑
Metabolic acidosis	↓	↓	↓ or normal
Compensated	normal or slightly ↓	↓	↓
Metabolic alkalosis	↑	↑	↑ or normal
Compensated	normal or slightly ↓	↑	↑

Quick ECG Interpretation



Normal Rate → 60–100 bpm

Normal P-R → 0.12–0.20 sec

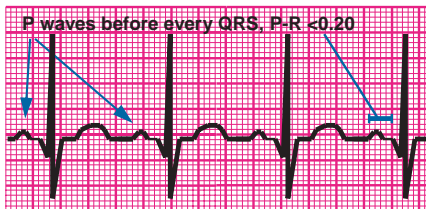
Normal QRS → 0.08–0.12 sec

P wave → atrial depolarization; **QRS** → ventricular depolarization; **T wave** → ventricular repolarization

0.04 sec

0.20 sec

Normal Sinus Rhythms



Rate..... Between 60–100

Rhythm..... Regular

P waves..... Present

P-R..... Normal

QRS..... Normal (0.08–0.12 sec)

Basic ECG Assessment

Follow these steps for basic electrocardiogram interpretation.

1. Determine ventricular rate.
2. Determine QRS duration and shape.
3. Identify P waves and determine if a P wave precedes every QRS complex.
4. If more than 1 P wave precedes a QRS complex, determine ratio of P waves to QRS complex (ex., 4:1, 3:1, 2:1).
5. Is P wave shape consistent?
6. Determine atrial rate and rhythm.
7. Determine P-R intervals and if they are consistent.

Analyzing the P-R Interval (PRI)

- PRI is consistent and between 0.12 and 0.20 sec (3–5 small boxes): This is considered a normal PRI.
- PRI is <0.12 sec (3 small boxes): consider junctional rhythm.
- PRI is longer than 0.20 sec (5 small boxes), it remains consistent in length from PRI to PRI: Consider 1° AV block.
- PRI undergoes progressive lengthening until a QRS is dropped: Consider 2° AV block, type I.
- PRI is consistent; however, there are additional P waves that do not precede a QRS complex: Consider 2° AV block, type II.
- PRI is not consistent, nor is there any correlation between the P wave and the QRS: Consider 3° AV block (CHB).

Analyzing the QRS Complex

- QRS between 0.08 and 0.12 (2–3 small boxes): Consider normal.
- QRS >0.12 sec, “wide and bizarre”: Consider ventricular ectopy.
- QRS >0.12 sec (3 small boxes), with notched or “rabbit ears” appearance: Consider BBB.
- QRS preceded by 1–2 very narrow “spikes”: Think pacemaker.

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